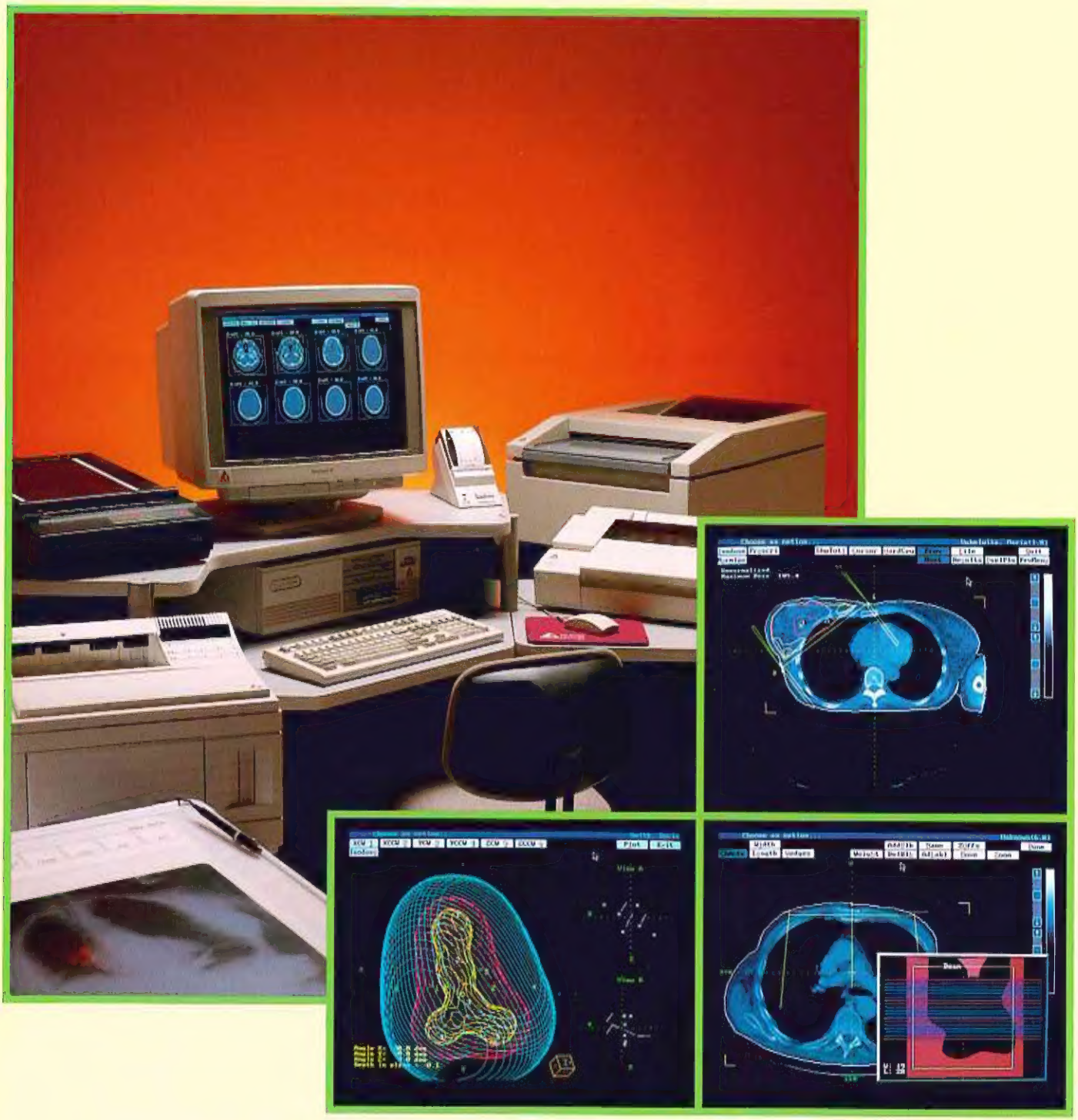
PROWESS 3000

CT Treatment Planning



Complete System

External Beam Planning *is quick and easy. Contours are entered from the digitizer or an optional CT interface. Beam calculations can be done using any combination of photon and electron beams.*

Brachytherapy Calculations *allow source entry from orthogonal and stereo films or from a template. Three orthogonal views are displayed on the screen. Use of the 3D localizing cube and isometric display with optional slices in windows aids in visualization of source location and dose distribution.*

Irregular Field Calculations *begin with field shape entry using the digitizer. Dose computation is done using an external Clarkson Integration model accounting for beam edge, varying SSDs and partial transmission blocks.*

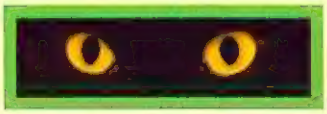
Machine Data Entry *is fast and accurate. Machine data can be entered directly from more than 8 models of 3D beam acquisition systems, from the keyboard or using the digitizer.*

Customized Systems

Prowess 2000's *modular design gives you tremendous flexibility in the selection of software. The Basic System includes the three main programs for external beam therapy, brachytherapy and irregular field calculations. You may select all or part of this basic system or move up to a Full System with a color film scanner which allows the use of diagnostic CT/MRI films or with a magnetic tape drive.*

Prowess 2000's *versatile and modular design enables it to greatly enhance all radiation therapy departments, large and small. By customizing the system, you realize the best possible value. Let Prowess 2000's speed and efficiency put your department on the cutting edge in radiation treatment planning today.*

Service Support



SSGI *has generated a strong user base and an international network for sales, support and demonstration sites. Your calls and questions will always be answered in a timely manner, being directed to the expertise you need. A 24-hour bulletin board is available for your immediate interaction with our staff.*

Quality documentation and an easy to use program is a combination which will make you an active user quickly.

PROWESS SYSTEMS

A TREATMENT PLANNING SYSTEM

USER'S MANUAL

Version 3.02

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PROWESS SYSTEMS

A Treatment Planning System

Welcome to the SSGI select group of software users. You have purchased a product designed with your patients and support staff in mind. All *PROWESS* products have been designed to be accurate, fast, easy to learn and use, and accompanied with detailed documentation. SSGI is dedicated to giving you continued support for your product with quick response to your questions, concerns and comments.

The front cover of this manual will reflect the version you purchased. However, this manual is under constant revision as is the software. Therefore, you will be receiving periodic update inserts for this manual. Until a full manual update is released, you will probably note various version numbers within this manual in the footers. Even though the footers may reflect a manual version number earlier than the version of software that you purchased, all information in this manual at your time of purchase is current.

SSGI disclaims all responsibilities for any inaccuracies in calculations by Prowess *3000*. All data entered is the responsibility of the user and all calculations must be checked by a responsible radiation oncologist or physicist before implementation. Prowess *3000* is not connected directly to any patient or x-ray source and cannot be held liable for such. All data used by Prowess *3000* is to be entered only by trained operators under the direction of a qualified radiation oncologist or physicist.

Written by Philip Heintz, Paul King, & Dave Childs.

Book design by Lillian Heintz & Debra McElroy

To Bret and Robert

INTRODUCTION TO PROWESS *3000*

SYSTEM OVERVIEW

PROWESS *3000* is a complete 2D multislice radiotherapy treatment planning system. It is organized in a modular manner and consists of a set of independent programs each of which provide a specific capability. Access is provided to all programs through a single main menu.

The programs are highly interactive using a mouse and/or keyboard driven graphical user interface (GUI) which was developed specifically for this application. An on-screen button bar provides context sensitive access to up to 20 operations at any given time. Various on-screen icons provide additional user control. All buttons and icons can be accessed using either the keyboard or mouse.

An on-screen status bar is continuously updated to provide constant feedback on the current process and pop-up boxes are used to provide and solicit supplemental information.

Programs are included which allow entry and editing of patient, treatment, treatment unit, implant, and brachytherapy source characteristics. Every effort has been made to make the use of these programs as intuitive and as simple as possible.

Every effort has been made to achieve product modularity, ease of use, and calculation speed. Though these are important, calculation accuracy has not been sacrificed to achieve them. PROWESS calculations are based almost exclusively on measured and precalculated data.

SYSTEM HARDWARE

PROWESS *3000* is a software system. The hardware selected to run the software is standard, commercially available equipment. Interfaces between the different hardware components use standard cabling (either parallel or EIA RS232 serial connections). The hardware components include:

- PC Microprocessor 386/486
- VGA Graphics Display
- Keyboard
- Digitizer
- Color Plotter

- Laser Printer
- Floppy Disk Drives
- Hard Disk Drive
- Mouse
- Magnetic Tape Drive (optional)
- CT/MRI Film Scanner (optional)
- Label Printer (optional)

USERS' MANUALS

The Prowess *3000* system is provided with the following manuals:

- PROWESS *3000* User's Manual
- MS DOS Disk Operating System Reference Manual
- Microcomputer User's Guide
- Graphic Plotter Operation and Interconnection Manual
- Digitizer Operator's Manual
- Printer Operator's Manual
- Magnetic Tape Drive Reference Manual (Optional)
- 6FS Film Scanner Operator's Manual (Optional)
- 14FS Film Scanner Operator's Manual (Optional)
- Label Printer Operator's Manual (Optional)

SYSTEM HARDWARE AND SOFTWARE

OVERVIEW

The basic hardware and system software is described in this section. The important features and operation of each hardware component are described with the details left to reference in the appropriate user manuals. The software design philosophy and organization are presented in this section. The details of each PROWESS *3000* program are described in the succeeding sections.

HARDWARE

General

Before discussing the PROWESS *3000* software, it is important to become familiar with the system hardware. PROWESS *3000* is a software system, therefore, basic knowledge of the operation of the hardware is important to use the software correctly.

The major hardware systems include the computer, keyboard, enhanced graphics display, floppy disk drive(s), hard disk drive, printer, plotter, digitizer, mouse or trackball, and optional magnetic tape recorder or CT film scanner. Each of these systems are described briefly and the salient points of operation discussed.

Note: Read all manuals provided with the system before beginning to use PROWESS *3000*.

Computer System

The PROWESS *3000* treatment planning system operates on an MS DOS compatible computer system using an Intel 80386 or 80486 microprocessor with a minimum of 4MB of RAM (8MB recommended). An Intel math coprocessor is required on all 80386 systems. A coprocessir is built into the 80486 and, therefore, does not need to be added. The graphics display is an important part of the computer system. The display must be a Super Video Graphics Adaptor (SVGA) with 512K of memory that allows up to 43 lines of color text displayed on the screen. The color monitor must use an SVGA display of at least 256 colors from a palette of 2,000,000

different colors. The SVGA graphics resolution mode is 640 x 480 pixels using all 256 color palettes.

The computer must have at least two RS232 serial ports and one parallel port. If the plotter is an HP PaintJet or other printer/plotter, then two parallel and one serial ports are required. These are used to interface the digitizer, plotter, and printer respectively. Mouse support is usually provided through a bus interface card.

The software operating system used by the computer is MS DOS 5.0 or higher.

Please read the appropriate sections of the computer user's guide discussing the computer system, keyboard, disk drives, hard disk drive, and the graphics display to learn how to operate the computer. These sections will discuss the following topics: Power on, setting the system date, setting the system time, using the keyboard, details of the graphics display, how to run a program, rebooting the system, and moving files on the computer.

Keyboard

The standard keyboard for the computer has the traditional QWERTY arrangement for the alpha keys. In addition to the usual numbers across the top of the keyboard, there is a numerical keypad on the right side. The two sets of numbers have exactly the same function. Included in and/or to the left of the numeric keypad are arrow keys that move the cursor. The ENTER and RETURN keys have the same function. They may be labeled differently. Across the top of the keyboard (or to the left) are ten keys labeled F1 through F10 called function keys.

Other functions of the keyboard are:

ESCape: This key is usually located in the upper left-hand corner of the keyboard marked with the letters ESC. This key is used extensively in the PROWESS *3000* programs to exit from one part of the program to another.

ALTernate: This key is important in the operation of PROWESS *3000*. A function is activated by pressing the ALT key along with the highlighted character in the function name.

ConTRoL: This key is usually located in the bottom left corner of the keyboard marked with the letters CTRL. This key is not used in PROWESS *3000*.

DELete: This key is usually located at the bottom of the numeric keypad on the 84 key keyboards and in the center cursor control area of the 101 key keyboards.

The combination of CTRL, ALT, DEL is used to reboot (restart) the computer without having to shut off the power or shut down the computer. **Note:** A reboot destroys all the information not saved on your hard disk.

Mouse

A mouse or trackball can be used in the treatment planning process. The mouse is moved by sliding it on a flat surface such as a table top or mouse pad. There are two or three active buttons on the mouse. The left button usually acts as the **Enter** key on the keyboard. The right button usually acts as the **ESCape** key.

To select a button on the screen, move the mouse to the area of interest and click once. If an item needs to be chosen from a list, move the arrow to the item and click the left button twice.

To select a beam, click on the active area of the beam and click. Hold down the button and move the beam to the position desired. Release the left button.

Hard Disk Drive

The computer uses an internal hard disk drive generally labeled drive C:. The disk must be formatted and have all system software installed. Refer to the computer operations manual for details.

The computer must be located in a place that is stable and free of vibration. The hard disk drive can protect itself by "parking" during transit, but it is easy to cause a "crash" if handled or moved while the power is on.

The main computer package and hard disk may be mounted either horizontally or vertically. If it is mounted vertically, a "tower stand" must be installed to provide stability.

The Norton Utilities software package is provided with the system for hard drive maintenance. These programs are easy to use and can assist with most problems. Refer to the software manufacturer's manual for complete instructions.

Diskette Drive

Floppy disk drives are used for installation of new programs and data, backup of the hard disk, and archival storage of patient data. The data storage format on these disk drives is the standard MS DOS format.

There are several types of floppy disk drives:
- 5.25", HD 1.2 MB
- 5.25", DSDD 360 KB
- 3.5", 1.44 MB or 760 KB

See the computer manual for instructions on operating the diskette drive. Do not leave floppy disks in the drive when the power is turned off.

For optimum diskette life and performance, floppy diskettes should be kept in their respective envelopes at all times except when in use. Never touch exposed diskette surfaces. Never fold or bend diskettes. Keep diskettes and all magnetic media away from strong magnetic fields, (e.g., magnetic paper clip dispensers) and protected from temperature extremes. Floppy disks are not suitable for long term storage of critical data. Always keep a backup copy of critical data along with a printed hard copy.

Before data may be stored on a diskette, it must be formatted. **Note:** Formatting a diskette destroys all previously stored data. *Do not* reformat diskettes which contain data that will be needed later.

Insert the proper floppy diskette into Drive A: or B:. Go to DOS (F10, F10 from the Main Program Menu). At the "C" prompt type:

C:> **format A:** (or B:)

and press ENTER when prompted by the computer. Answer the remainder of questions from the computer.

Once a diskette has been formatted, machine data files, program files and patient data files, may be transferred from the hard disk to the diskette for archival purposes using MS DOS copy commands. Refer to the MS DOS manual for details.

Backup

It is also recommended that the backup policies described in the *MS DOS Reference Manual* be followed in order to save all machine and system data in case of a hard disk failure.

For most systems, a cartridge tape backup system is installed. This is the easiest and fastest back up system available for the PC. Refer to the manufacturer's user manual for operation of the tape unit.

For systems without cartridge tape backup, the commercial program Fastback Plus™ is provided for fast and convenient system backup. Refer to the Fastback User's Manual for set up and operation.

The DOS program backup can also be used for backing up your hard disk. Refer to the MS DOS manual for operational details.

If your system has a 9 track magnetic tape, it may be used for back up. This offers a large storage capacity and is easy to use. If you choose to use this device, please refer to the included user's manual for operation.

Note: The hard drive should be backed up at least once a month. If the system is being used a great deal, then the back up should be done weekly. Remember, if the computer fails, all files created or changed since the last backup may be lost.

Position Digitizer

A position digitizer is used to specify the location of a point while operating a PROWESS program. The position digitizer is used by the external beam program for patient contour and block outline entry, by the irregular field program for beam outline entry, by the brachytherapy program for source localization and by the machine data entry program for %DD and OCR curve entry.

A position digitizer consists of four components. These are the stylus, tablet, receiver, and control unit. The digitizer can be operated in either a point entry mode or a continuous entry mode. To operate in the point entry mode, press the point of the stylus against the surface of the tablet until it clicks, then release. To operate in the continuous entry mode, click the stylus to the tablet and, while maintaining pressure, trace out the curve or contour.

The surface of the tablet is covered with a protective plastic sheet and marked as shown in Figure 2.1.

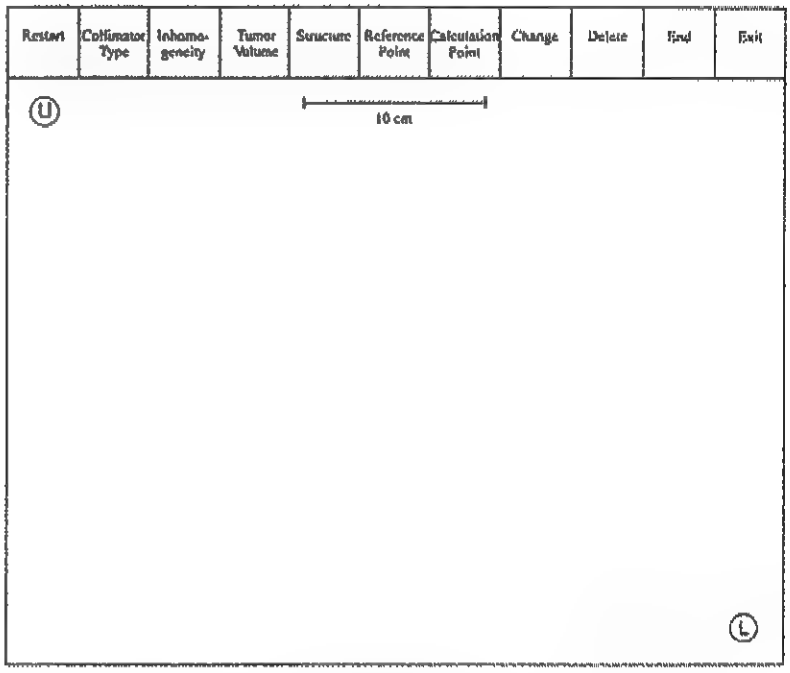


Figure 2.1 - Active Area of the Digitizer

The features of this tablet surface include a large open area for placing contours, plots and films, two points "U" and "L" which are used to calibrated the scanner, and eleven square regions marked as buttons. To select one of the options indicated by the button name, digitize a point inside the button. The function of these buttons is as follows:

Restart - Restarts entry.
Collimator Type - Allows change of collimation type.
Inhomogeneity - Allows entry of a heterogeneity.
Tumor volume - Starts entry of a tumor contour.
Structure - Starts entry of a structure contour.
Reference Point - Allows entry of reference points.
Calculation Point - Allows entry of calculation points.
Change - Allows change of the brachytherapy source type or strength. In the Machine Entry module, allows change of curve number.
Delete - Deletes points.
End - Ends an entry procedure.
Exit - Terminates all entry from the digitizer.

To obtain the most accurate results while using a digitizer, always keep the stylus perpendicular to the tablet surface. The active area of the tablet is indicated by backlighting and points cannot be digitized outside the active area. Since positions are digitized by interpretation of the signal detected by the receiver, it is important that nothing interfere with the signal as it is transmitted from the stylus to the receiver. An acoustic digitizer's receiver (microphone pair) is located on the surface of the tablet. Ensure that the blue stripe on the stylus points in the general direction of the receiver and that nothing blacks the path from stylus to receiver. Note that accurate results cannot be assured when the stylus of an acoustic digitizer is within 5 cm of the receiver. An electromagnetic digitizer's receiver (wire grid) is located just below the tablet. To assure accurate results, keep metal objects out of the general vicinity of the stylus.

Plotter

PROWESS *3000* system uses the Lexmark PS4079 color printer, the Hewlett Packard™ PaintJet XL printer with HPGL cartridge, the HP PaintJet XL300 printer with postscript, the HP 7475A plotter, the HP 7550A plotter, or most HPGL compatible 6-8 pen color plotters to produce high quality color plots on standard paper. The manufacturers of these plotters provide very comprehensive manuals with their units. The operator's part of each specific manual should be read before proceeding to operate the PROWESS *3000* operating system.

The single sheet plotter, HP7475 or compatible, uses one sheet of paper at a time. Each sheet must be manually loaded into the plotter before a plan is plotted and manually unloaded when the plotter has finished. The single sheet plotter accepts paper from 8½"x11" to 11"x17".

To obtain plots of the highest quality, it is important to use pens appropriate for the application. For normal plotting on paper, use water based pens.

To load an 8½"x11" sheet of paper in the manual plotter, release the paper load lever and place the paper on the plotter so that the 11" side is parallel to the front of the plotter. Slide the paper up to the white line. Clamp the paper in place using the paper hold down lever. After the plot is complete, remove the paper by lifting the lever.

Printer

The standard text printer for the PROWESS *3000* system is the Hewlett Packard LaserJet 4m. This printer also can print CT images

with the treatment plan overlaid as well as produce black and white HPGL plots. Alternately, an Epson-compatible, wide-carriage, 24-pin, dot-matrix printer can be used.

It is important that the operator's part of the user manual for either printer is read in order to become familiar with the features of the printer. This guide describes the set up procedures, use, and maintenance of the printer.

Printer/Plotter

The preferred devices for CT hardcopy printing and plotting are the Lexmark PS4079 with postscript, the Hewlett Packard DeskJet 1200 C/PS, or the HP PaintJet XL300 with postscript. These printers not only allow you to print your CT image in gray scales, but they also overlay color coded isodose lines which correspond to a list of the doses on the right side of the paper. The beams and contours are outlined in black. This allows you to see exact doses in specific locations on your CT image.

These printers have automatic paper trays which hold up to 100 sheets of paper. Both 8½"x11" and 11"x17" sizes of paper trays are available on the PaintJet XL300 and the Lexmark PS4079.

These devices will both print and plot, however, in order to print text-only documents, it is recommended that you also have an HP LaserJet 4m or Epson-compatible, dot-matrix printer installed.

Magnetic Tape Drive

The reel-to-reel magnetic tape drive option is used to read CT and MRI tapes from various imaging equipment. The unit reads ½" wide, 9 track magnetic tape at 800, 1600, 3200, and 6400 bits/inch.

The read/write heads on a magnetic tape unit gets dirty quickly as the unit is used. Clean the head every 2-3 tape readings. To clean the head:

- Turn the power OFF.
- Wipe the head with a cotton swab dipped in a good grade of ethyl alcohol.
- Let the head dry.
- Turn the power ON.

A tape unit can be used to back up a hard disk. Look in the Operator's Manual for your tape unit for the procedure.

Loading a Manual Unit: Place the magnetic tape on the lower hub and lock the hub. Thread the tape around the rollers and through the heads. Wrap the tape around the take-up wheel (upper hub) and spin the upper hub to be sure the tape sticks. Press the load button and remove the write-protect option. Select the correct speed (H for AK Systems drive).

Loading an Automatic Unit: To operate the unit, pull down the load cover, slip the tape reel into the unit and locate it on the hub. Close the front cover and press **Load**. When loaded, press **On Line**.

CT/MRI Film Scanner System

Two film scanners are available to read CT or MRI images.

6FS Scanner: The 6FS film scanner is an 8½"x14" flatbed scanner with a light bar attached on one side. The other side is open to allow placement of films wider than 8½".

When using the film scanner, be sure the power is on. Both the green and yellow lights must be lit before scanning a film. The scanner has a calibration strip at the top of the scanner bed. Ensure that this strip is not obstructed.

The scanner should be allowed to warm up at least 15 minutes before making the first scan. The bulbs have a finite lifetime and should be replaced every six months with normal use.

14FS Scanner: The scanner must be warmed up for at least 15 minutes prior to use. The 14FS film scanner is a large scanner capable of reading a 14"x17" film. The film is placed against the rollers on the front of the scanner. The scanner will grab the film and pull it through the unit as it reads the film. Once scanned, the film is fed back out the front.

Label Printer

The daily calculation program uses a label printer for hardcopy. Before using the printer, turn it on by pressing the left button with a ⇻ symbol on the key. The right button is used to advance the labels.

Use only labels approved by the manufacturer. Load the labels by dropping the roll into the hopper and feeding the leader through the front roller. Advance the labels to the first perforation. The label printer must be attached to a serial port for operation.

Power Protection

It is recommended that a power protection device be used to protect the computer from power surges on the incoming line. If power failures and sags are common, then an uninterruptable power supply is recommended.

TESTING THE SYSTEM

Many simple diagnostic tests may be performed to evaluate the operation of the computer and peripherals. The computer runs its own self test at the time of power up. The self-tests for the printer and the plotter are described in the user's manual. It is helpful to run these tests before calling a service representative if problems occur with the system. PROWESS *3000* has a program called **Device Testing**. This should be run after installation or when there is any question of a hardware problem. The operation of this program is described later in this chapter.

INSTALLATION NOTES

Before the PROWESS *3000* system can been installed, data must be collected for each mode of each therapy machine in the department. The data required is discussed in the Machine Data Entry section. The hardware must be installed according to the manufacturer's specifications. Refer to the appropriate user's manuals for details.

After the system has been installed, the following procedures must be performed: (a) The system must be turned on and the start up files checked for completeness, (b) patient floppy diskettes must be formatted for archival storage, and (c) machine characteristics must be created for each therapy machine and mode of operation. These machine characteristics must be stored in the machine directory and backed up on a floppy diskette.

DAILY START UP & SHUT DOWN

The equipment should be **Turned ON** according to the original manufacturer's recommendation. Refer to the appropriate user's manuals whenever necessary. Before power is supplied to any of the units be sure that all cable connections are tight. Where possible, cable connections should be made using the screws provided.

The order of turning on the power to the units is not critical except for the magnetic tape device. Turn this unit on after the computer has reached the **Main Menu**. Switches are located near the power cord on most units. At the time the power to the computer is turned on, be sure no floppy diskette is in the top drive (drive A:). This action forces the computer to boot from the hard disk. If a common power

controller has been included for all components, simply turn on the main power switch.

When all units are on, the computer displays the PROWESS *3000* main menu. This menu may differ at each installation, depending upon the ancillary or the support programs operational on the computer. To activate one of the programs, simply select the desired program such as Treatment Planning using either the cursor keys or the pointing device.

To shut down the system, exit from the program that is operating and return to the main system menu. If using a word processor, it is imperative that the word processor is exited, then return to the main menu before turning off the power to the computer. Once the main menu is on the screen, turn off the power to all units. The order of power down is not important.

OPERATING PROWESS *3000*

Operating PROWESS *3000* has been made easy, as the software has made full use of the hardware features of the microcomputer. Operations are activated by selecting the function using the ALT-(letter) keystroke. Alternately, the mouse may be used to select the function. Pop-up windows are used to enhance the functions. The active labels for the keys are displayed on the screen as discussed earlier. Should you forget where you are or want to **EXIT** the program, press the ESC key until you return to the **Main Menu.**

Every effort has been made to minimize your movement between the digitizer and the keyboard. The order of data entry has been grouped to achieve optimal use of each hardware component. Use of the digitizer menu keeps you from switching between the two devices. The screen keeps you informed as to your next entry, even for the digitizer, by requesting information or showing its action in the **Action Line** above the function window.

The basic flow in the PROWESS *3000* system is shown in Figures 2.2 through 2.6. Upon completion of a program the system will return to the treatment planning **Main Menu.** Found on the second page of the treatment planning menu are the utility functions for editing machine characteristics. These programs are reached by touching the "C" for Configuration/Data Entry and a second menu page appears.

Once the desired program is chosen, it will request information from either the keyboard or the digitizer. Beam outlines and patient contours may be entered from x-ray films placed on the digitizer, CT scans, or scaled drawings. Brachytherapy radioisotope sources may be entered from the digitizer or the keyboard. Results are displayed on the viewing screen and can be transferred to the printer and plotter. The printed copy should be put in the patient's chart along with a manual calculation to verify the accuracy of the results.

All programs, system modules, and machine data are stored on the hard disk of the computer. Patient data is kept together on the hard disk in one subdirectory with machine data and radiation source data in a second and the program modules in a third. A floppy diskette should be used for long term archival storage of patient data files. As a patient directory is built, it may be transferred to floppy disk for permanent storage. It is recommended that no more than 50 patient files be kept on the hard disk at any one time.

Note: The maximum number of patient files that can be stored in a directory is 500. More than 500 files will produce an error not allowing you to display all the files for recall. When this error occurs, either create a new patient directory or delete some of the patient files.

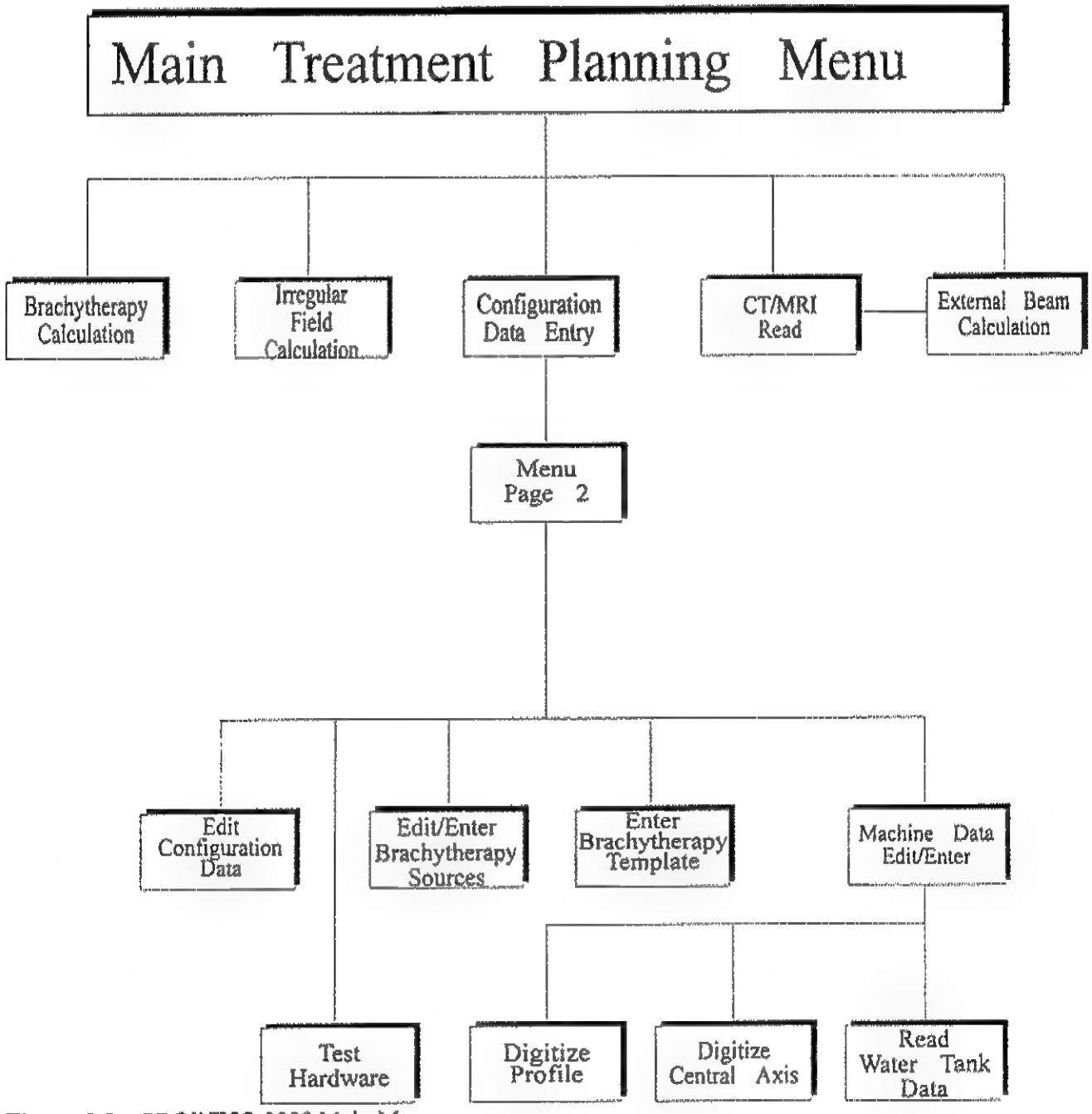


Figure 2.2 - PROWESS *3000* Main Menu

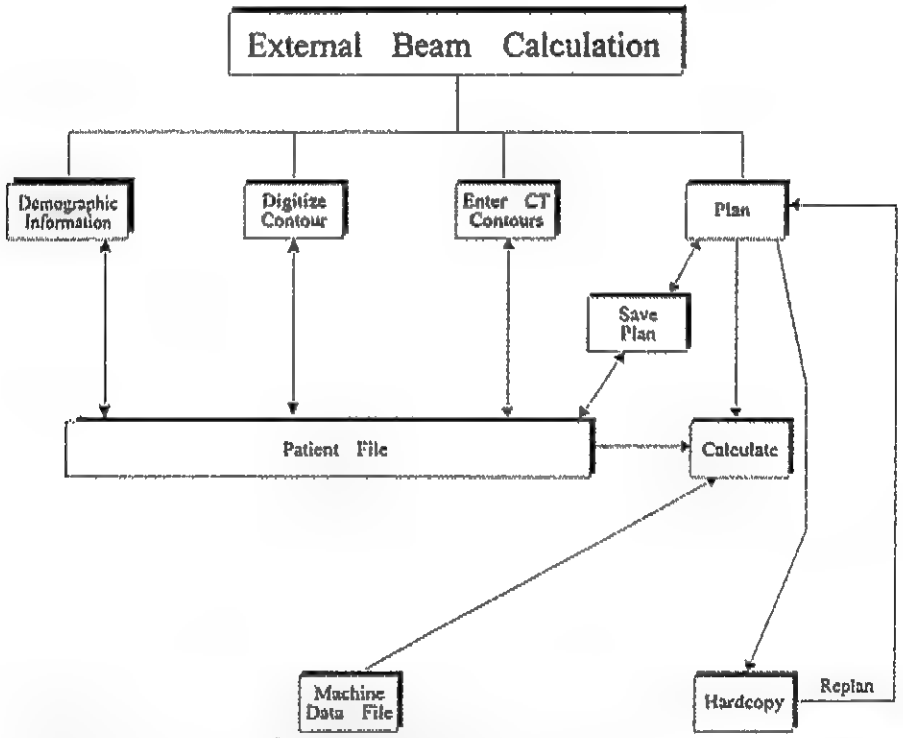


Figure 2.3 - External Beam User Interface Calculation

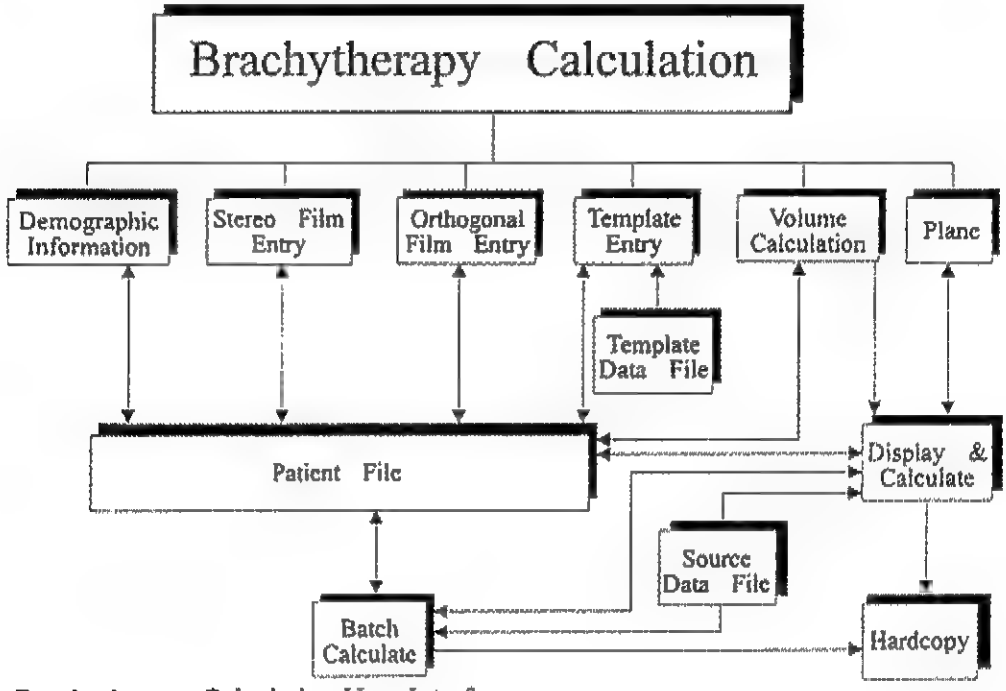


Figure 2.4 - Brachytherapy Calculation User Interface

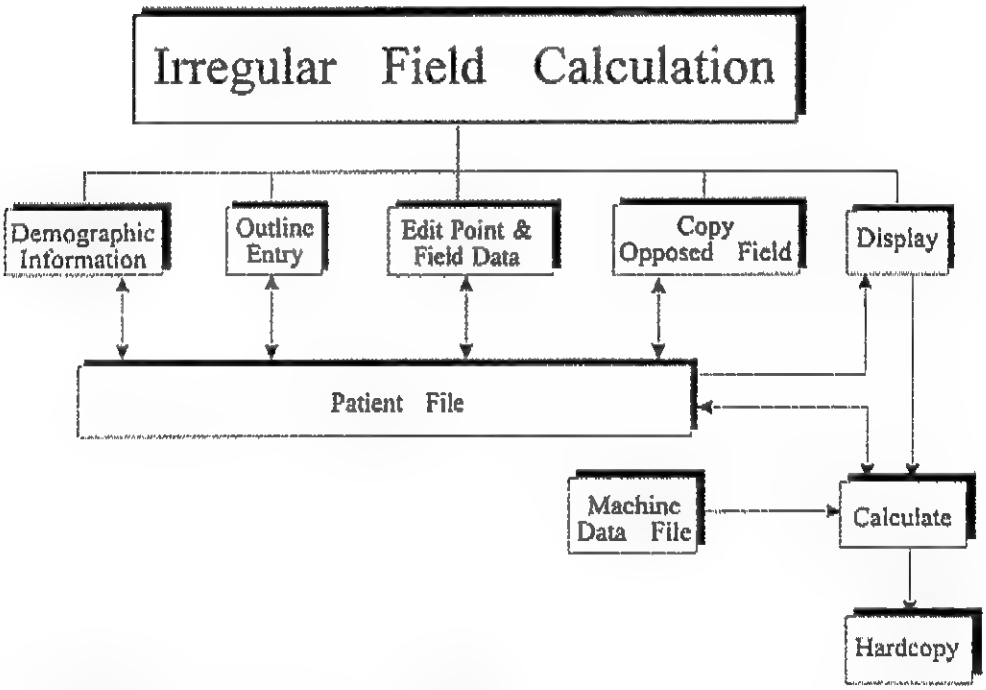


Figure 2.5 - Irregular Field Calculation User Interface

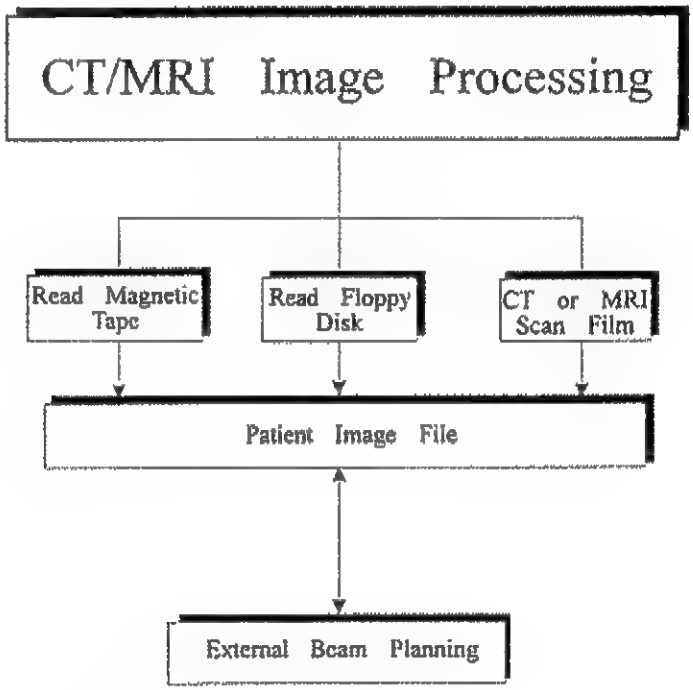


Figure 2.6 - Image Entry User Interface

STARTING PROWESS *3000*

Following initial startup, you may reach the treatment planning menu from the main menu by selecting TPS. This brings up the treatment planning menu. From this menu select the appropriate treatment planning program as shown below.

To choose the desired option, move the UP or DOWN arrow keys to the desired program (highlighted) and press **Enter** or press the key of the first letter such as B for Brachytherapy Calculation.

MAIN TREATMENT PLANNING MENU

- External Beam Planning
- Brachytherapy Calculation
- Irregular Field Calculation
- Daily Calculation
- Read CT/MRI Tape Images
- Scan CT/MRI Images
- Configuration/Data Entry
- Quit or the ESCape key exits Menu

CONFIGURATION/DATA ENTRY

- Edit Configuration
- Machine Data Entry
- Brachytherapy Source Entry
- Template Entry
- Device Testing
- File Management
- Quit Configuration Menu

Units

A standard set of units are used throughout this manual and implemented into the program. All linear dimensions are specified as centimeters unless otherwise specified. Doses are specified in cGy or dose rate in cGy/hr. Units of activity of radiation sources vary with the data but are shown on the screen. These may be in mCi, mg Rad eq., Becquerels, or air kerma. Densities are relative to water whose density is specified to be 1.0 g/cm^3.

File Manipulation

Executable programs, patient data, and machine data are stored as files. Each file has a unique name consisting of 1-8 letters followed by a period and a 3-letter extension. The files are organized or grouped on the disk drive in a directory or subdirectory. Like a diskette, a directory on the hard disk can hold a number of files. The upper

floppy drive is labeled Drive A:, the lower floppy Drive B:. Hard disk drives can be divided into several drives (e.g., Drive C:, D:, etc.).

The computer operating system used by PROWESS *3000* is MS DOS 5.0 or higher. Within MS DOS, certain file label conventions must be followed. A back slash "\" is a directory name delimiter. This tells the operating system that the name following the slash is a directory name and not a file name. To specify the directory name PATIENT on Drive C: you would type C:\PATIENT. To specify the file robert.txt in the directory PATIENT you would type C:\PATIENT\robert.txt.

The hard disk has many directories that are active for the users during the operation of PROWESS *3000*. "\" is the root directory and holds the Main Menu and directs traffic. The following list describes the directory tree used by PROWESS *3000*.

\TPS3 - Main treatment planning directory under which all of the programs and data are stored.

- \Bin - holds all of the executable (*.EXE) programs and the compiled configuration control file (TPSCTL.CTL).
- \Font - holds the fonts used for display on the screen.
- \Image - holds graphical images used for screen display.
- \Patient - contains the patient files (*.EXT, *.IRG, *.BCY)
- \Machine - contains machine data files (*.MCH) and brachytherapy source files (LINESEED.SRC).
- \Catimage - contains CT image files (*.CAT).

The diskette drive A: is used for archival storage of patient data.

Patient file copying, deleting, and archiving can be done using MS DOS™ commands or the file management option. This option utilizes a program called Pop-Up DOS™. The user's manual for these programs are included in the reference documentation. It is easy to use, especially with the aid of the mouse. Appendix C is a summary of the Pop-Up DOS™ commands needed to manipulate the Prowess files.

HARDWARE TEST

The program option entitled **Device Testing** found on the Configuration/Data Entry menu tests the PROWESS *3000* hardware

devices. These devices include: Digitizer, mouse, modem, printer, plotter, magnetic tape drive, and scanner.

Following installation of the PROWESS *3000* system software, this program should be run monthly and after any hardware service. The program can also be used to help troubleshoot hardware and software problems.

To run the program, follow the directions in the pop-up windows. Once the test menu appears, choose the function for each hardware device. Take any action requested by the program. The results of each test are displayed on the screen. Should a device fail the test, check the device to be sure that it is plugged in and turned on. This can be used to check device operation and paper control file configuration.

If, after taking all of the appropriate correctional measures, the device still fails, please contact the closest PROWESS *3000* representative for assistance.

UPDATING PROWESS

The update diskettes are 5¼", 1.2 MB format or 3½" format, 1.44 MB.

Backup Current TPS System

Before installing any update, back up your current system software. Most users will have a cassette tape backup. Follow the directions below to use the cassette tape backup option. If you have a 9 track magnetic tape unit, back up the entire hard disk with FLASHBAK. If you do not have the tape units, use FASTBACK. If you have a cassette tape, use the cassette tape backup.

Fastback

To back up with FASTBACK, it will take up to ten, 5¼" high density diskettes depending upon the number of patient and CT files on the disk. Have these ready before starting. They do not have to be formatted. Everything on these diskettes will be written over. Label the diskettes, as soon as they are used, with the date and volume number.

Start FASTBACK from the main menu.
Choose BACKUP
Using the cursor keys, choose: INCLUDE FILES
Enter \TPS for directories
. for files

Y for subdirectory
Press ESCape to exit editing the Include Files
Choose START BACKUP. A new screen appears
Insert your first 5¼" diskette
Choose START BACKUP and press **Enter**
If you choose ESTIMATE this will give an estimate of the number of floppy disks needed (divide number by two for a better estimate).
Answer any questions the program prompts.
Insert diskettes as requested.

When the backup is finished, exit the program with a couple of ESCapes and a Quit. You are now ready to install the update. For further details on FASTBACK refer to the manufacturer's manual.

Cassette tape backup

To back up with the cassette tape drive, select tape backup from the main menu. Check to be sure the date and time are correct. Load a tape into the tape drive.

Be sure it is formatted. If it is not, select utilities and format tape (this process takes about one hour per tape).

If the tape is not new and overwriting the existing data is acceptable, select utilities and quick erase.

Once the tape is ready, select backup then wait for completion. Give the back up a name such as the date.
Note: If there are more than 80-120 megabytes on the hard disk, more than one tape may be needed.

Installation of Update

Leave the Main Menu by pressing F10 twice. The DOS Prompt (C:\) appears.

Before installing the update program, please run **chkdsk/f** to check the integrity of the hard disk.
Put Disk #1 in drive *A:
Invoke the install program by typing **A: INSTALL**
Answer the questions and put the diskettes in drive A: by number, as requested.
After the update is installed, type C: and press Enter.

If there are any questions about the update call the SSGI office for support.
*If the diskette used is in drive B:, replace all A's with B's.

EXTERNAL BEAM PATIENT ENTRY

GENERAL

The external beam treatment planning process consists of three general steps. The first step is to enter a set of anatomical and geometric data which describes a patient. This first step is addressed in the present chapter. The second step, covered in the next chapter, is to specify and position a set of beams on the patient and calculate the resulting dose distribution. The third step, covered in the following chapter, is to save and make a hardcopy print of all planning results.

There are two types of patient data which may be entered for external beam planning. These are anatomical image data and geometric contour data. Each patient is divided into a set of patient slices. As shown in Figure 3.1, each patient slice is divided into a contour slice and an image slice.

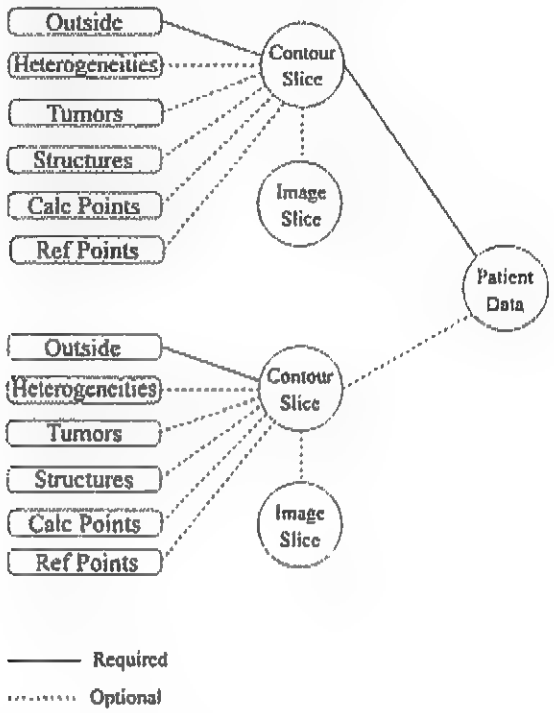


Figure 3.1 - Structure of Patient Data

Since image data is not used in calculations, the contour slice is required and the image slice is optional for each patient slice. Any images in a patient field without associated contours cannot be used for external beam planning. Each patient slice is parallel and offset from all other patient slices. Each contour slice is required to have an outside contour and may optionally have internal contours and points. Thus, the simplest patient data set might contain only one outside contour whereas a complex data set could contain much more information.

Image slices can be entered from a film scanner, magnetic tape, or diskette. Contour slices can be entered from the digitizer or mouse or they can be generated from image slices. Keyboard entry is required for demographics entry as well as parts of the contours and image slices. This is illustrated in Figure 3.2.

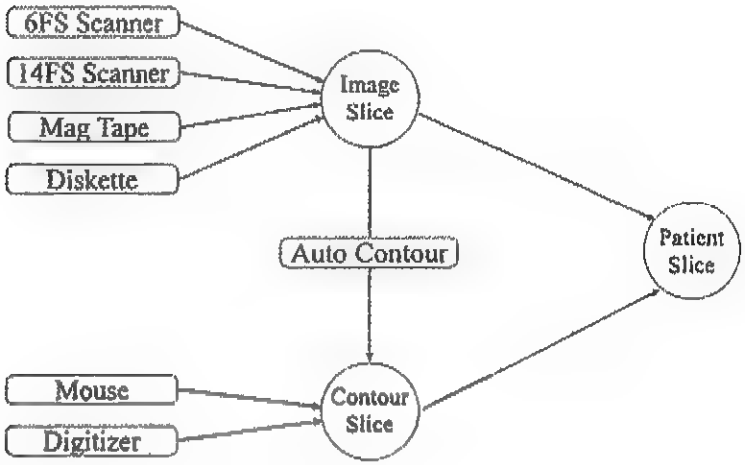


Figure 3.2 - Patient Data Entry Flow

DEMOGRAPHIC ENTRY

When a new patient is first entered, the demographic data is prompted for as shown in Figure 3.3. To modify this data from the main external beam planning window, Select Demogr.

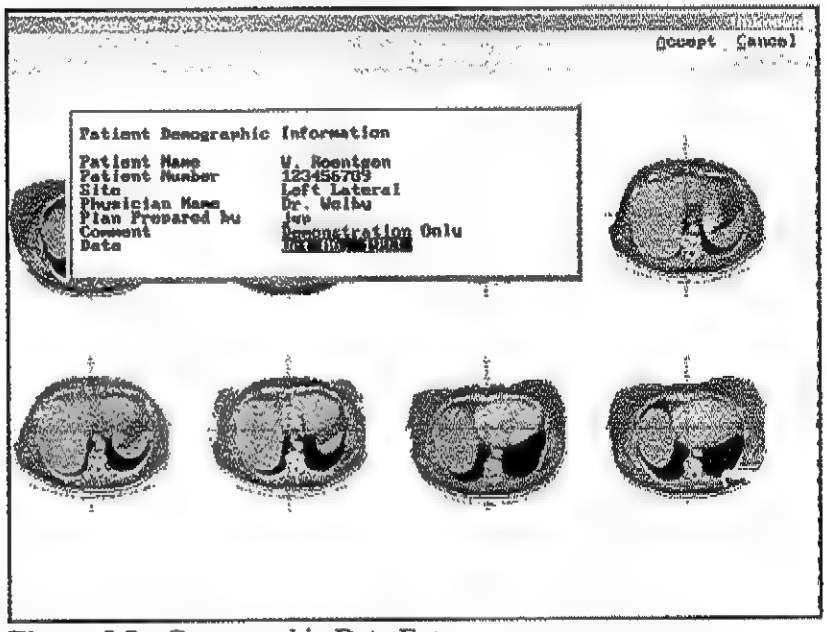


Figure 3.3 - Demographic Data Entry

IMAGE ENTRY

From Magnetic Tape

To enter CT images from magnetic tape, load the magnetic tape into the tape unit. Choose **Read CT/MRI Images** from the main treatment planning menu. Be sure the load light is ON and the correct density is selected (e.g., 1600 bpi). Check that the correct CT scanner is shown on the screen when you start the program. The program reads the tape header and displays the patients, procedures, and number of slices on the tape. Choose the patient desired and press **Enter**. As each image is read and formatted, the slice number is displayed on the screen. When the transfer is complete, the total number of slices is displayed. Press **ESC**ape, choose another patient for transfer, or choose **P**rocess.

From Diskettes

To read CT images from a diskette, place the diskette in the appropriate drive. Choose the Image file source (e.g., Siemens, Varian, Kermath, or Nucletron) to Prowess Convert selection from the main treatment planning menu. The program displays the files on the diskette. Enter or edit the demographic data. Then choose **T**ransfer. As each image is read and formatted, the slice number is displayed on the screen. When the transfer is complete, the total number of slices are displayed. Then choose another patient or

another diskette. When finished, choose ESCape to exit or Process.

From the 6FS Scanner

Before entry, be sure that the external scanner arm is installed in the scanner, turn the power on, and verify that both green and yellow lights on the front panel of the scanner are lit. Position the CT images on the scanner without covering the calibration strip at the head of the scanner. Choose ScanCT images from the main treatment planning menu. Enter the demographic information and Accept. The options are presented as shown in Figure 3.4.

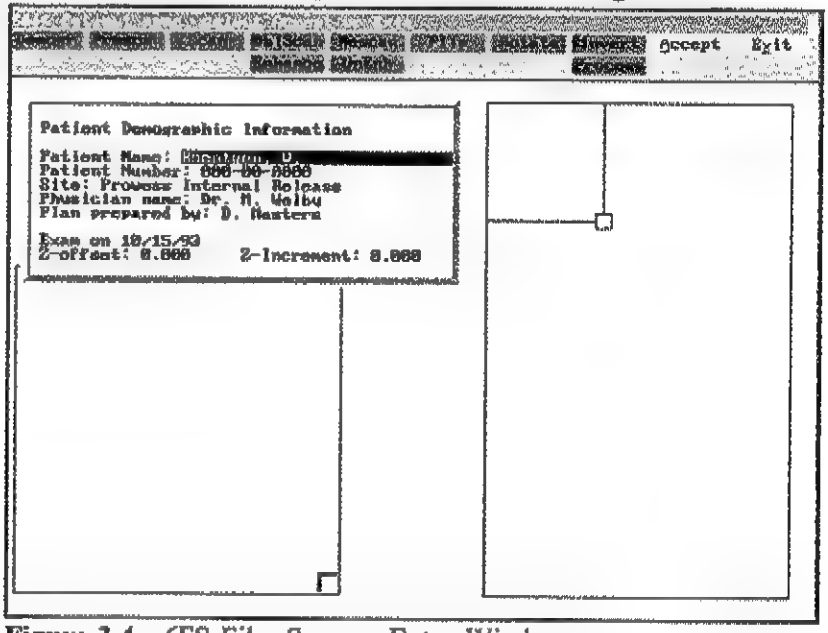


Figure 3.4 - 6FS Film Scanner Entry Window

Select Prescan. A scan is made of the entire active area. A large square box appears in the prescan image area to the right on the screen with a small box in the lower right corner. This large box is the area which will be selected to be scanned. The area to be scanned appears as a blue box with a small box in the corner.

Use the mouse to move this box and change its size, stretch or shrink. To move the box, place the mouse into the center of the area, hold the left mouse button down and drag the box. Release the mouse button to release the box. To change the size of the box, move the mouse to the small box, hold the left mouse button down and drag the mouse. The square box now changes size.

The fastest way to get the area you want covered is to move the large box and set the upper left corner in place. Then change the size to cover the region of interest.

When the box is released, a low resolution image of the area to be scanned is shown in the small scan box. Use this image as a guide to be sure the area selected covers the area to be scanned.

Once the area is chosen, select Scan or DblScan to scan the area. DblScan generally produces a better image. Following the scan, the small scanned area is replaced with the high resolution image and new features become active on the menu as shown below.

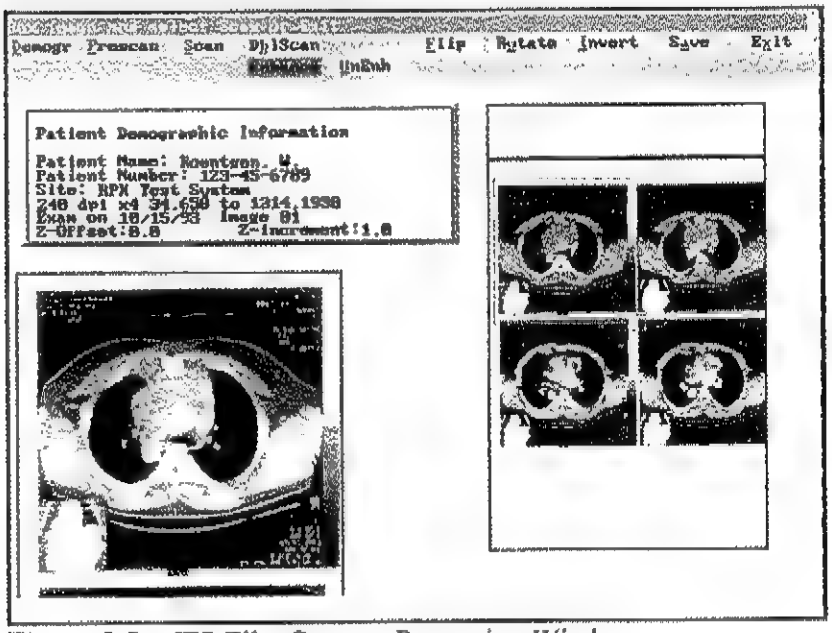


Figure 3.5 - 6FS Film Scanner Processing Window

You may now manipulate the image by inverting, flipping, and/or rotating the image until it appears in the correct orientation on the screen. You may also rescan it if the area chosen is not correct or the image is rotated slightly. Be sure the image orientation is correct as these functions are not available in the external beam planning.

The image has been digitally enhanced. To remove the enhancement, choose UnEnh and the raw image will appear in the scan window. The image enhancement is a modified histogram adjustment.

Multiple images may be scanned before leaving the module. Move the image scan box to the new area of interest and scan again. Each of these images are sequentially labeled. Enter images in increasing section numbers to make it easier to keep track of the images selected.

Once all images have been entered, you may then exit by choosing **Q**uit or choose Process to proceed to mark up and plan using the scanned images.

From the 14FS Scanner

Warm up the scanner for at least 15 minutes. Position the CT in the scanner bed against the rollers. Choose **Scan CT Images** from the main treatment planning menu.

If acquiring images from the film densitometer program, choose **C**T Acquisition. Enter the demographic information.

Choose **S**can to read the whole film. Once the film is read and displayed on the screen, a new series of menu items appears:

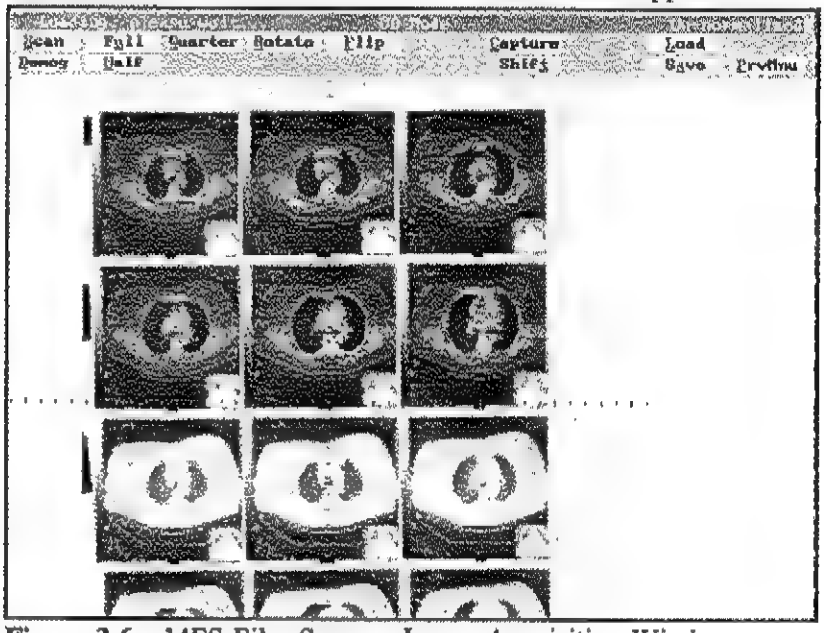


Figure 3.6 - 14FS Film Scanner Image Acquisition Window

To acquire the image, select the appropriate zoom box. Move the box using the mouse to center the image on the box. Then choose the correct orientation for capture. Choose **C**apture to store the

image. If more than one image is required, move the box to the next image and choose capture.

Before capturing an image, be sure the correct orientation is achieved. The image cannot be changed once in the external beam planning module.

The whole film image can be stored for future reprocessing by choosing Save to store the 1024 x 1024 12-bit image on the hard disk (-2MB image). To recall a saved file, choose Load and select from the list of film files displayed.

When all the images have been captured, choose Process to start the planning process or Quit to exit the scanning program.

Slice Management

Choose Slices to view all the available slices for this patient. They are displayed in order of Z-offset. No two slices can have the same Z-offset. Choosing this option brings up the following menu items:

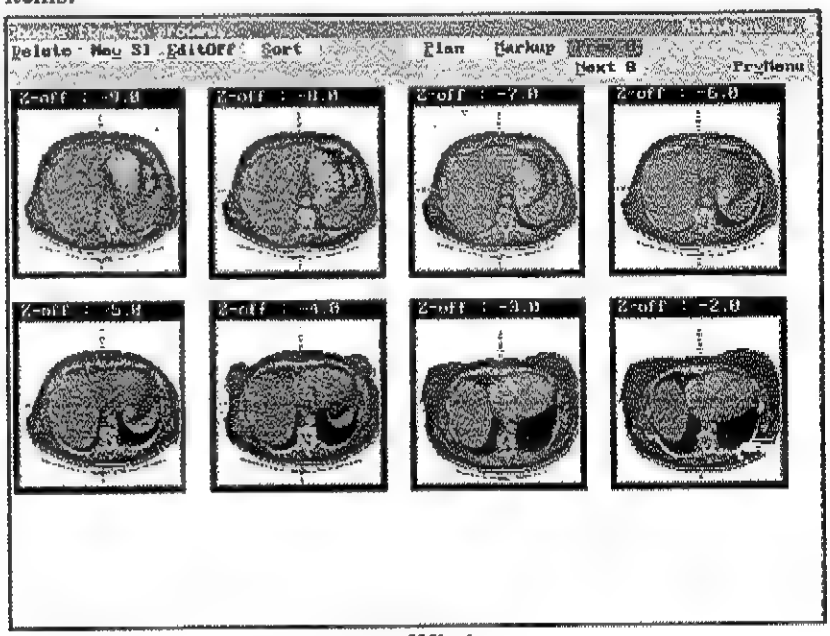


Figure 3.7 - Slices Management Window

The active slice is highlighted in red. It may be chosen by clicking the mouse on that image or using the arrow keys to activate the image.

A new patient to be entered using the digitizer starts with only one blank slice. Create all the slices needed for this patient before proceeding by choosing NewSl. Be sure to enter the slice Z-offsets for the new slices. At any time, the slice offsets may be changed by selecting EditOff. After changing the Z-offset, the order of the slices can be arranged in increasing Z-offsets by selecting Sort. If more than eight slices are entered for a patient, the slices not shown on the screen can be displayed by choosing Next8 or Prev8 from the menu.

A slice or image may be deleted by choosing Delete from this slice manager screen. Before deleting the slice, confirmation is requested.

Image Processing

The image may be doubled or halved by selecting Zoom. The image is always displayed in the 256 x 256 format, only the magnification is changed.

Selecting Origin allows the default of the image to be changed. Using the mouse, place it where the new origin is to be located and click. Once the origin is located, select "yes" or "no" to indicate if all origins are to be changed.

The sliding scales to the right of the grey scale image are used to adjust the window and level of the image. Check on the upper boxes to change the window and lower the boxes to change the width. Grab the center slider with the mouse and move it up and down to dynamically change the window and levels. Release the slider and the levels will remain set. From the keyboard, the up/down keys change the center or level of the window. Left/right keys change the width or contrast of the window. Adding Shift to the arrow keys speeds up the window changes.

To process the image further, before or after contouring, choose Tools. This selection brings up a new set of menu items.

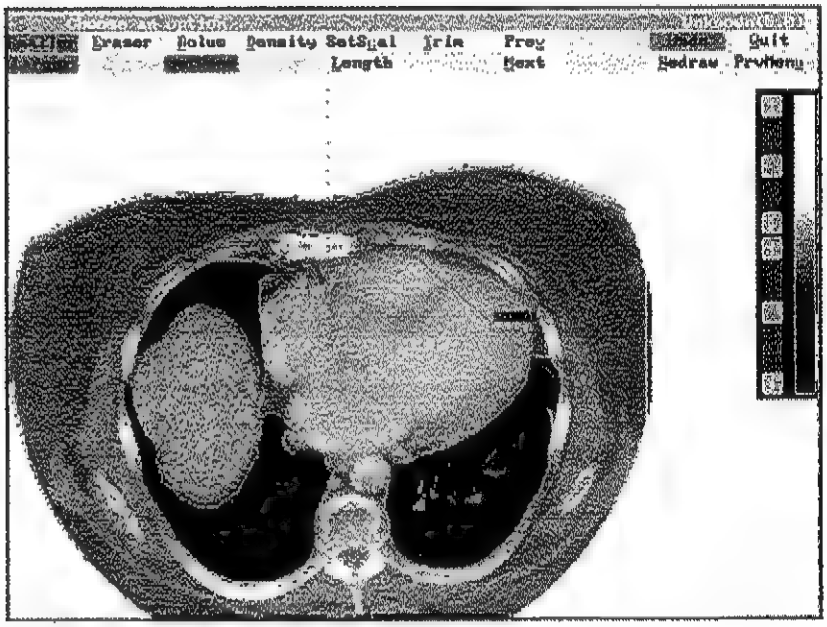


Figure 3.8 - Image Tools Window

Part of the image can be erased by selecting Eraser. A square box appears on the screen. It works like a blackboard eraser. The box may be made bigger or smaller by choosing the appropriate menu keys as shown above. To erase, move the eraser box over the area to be erased and press the left mouse button or the **Enter** key. Holding down the left mouse button while moving the mouse gives continuous erasing. Mistakes can be corrected by choosing Undo. The results are saved by choosing Accept.

Erase can be used in situations where there is no blank space surrounding the image. Auto contour needs the blank area to find the edge of the image. Sometimes the scout views get overlapped on the image producing a strangely shaped patient when contoured. This can be eliminated by erasing the unwanted image adjacent to the patient image.

The image may be repaired or bolus added by choosing Bolus. The function behaves just the reverse of the eraser. It adds a uniform density image within the box. To change the bolus density, choose SetDens and enter a CT value from -2000 to +2000.

The average CT density inside a square area may be found by selecting Density. As in Eraser, the box may be changed in size

by choosing the appropriate function menus. The pointing device moves the box. Pressing the left mouse button or the **Enter** key produces the average image density numbers inside the box. An **ESC**ape exits this function.

After the outside contour has been entered, all of the scan information outside this contour may be deleted. Selecting **T**rim eliminates image data outside the contour.

If the image becomes smeared or a mistake is made, undo or redraw the image. **U**ndo removes the changes made since this mark up mode was entered. **R**edraw just redraws the image.

To perform accurate multi-slice plans using a scanner, all the slices must be scaled correctly and must have a common origin. To achieve this uniformity, a few simple rules should be followed.

First, when the image is acquired during scanning, be sure all slices are scanned with the same magnification. Select the appropriate zoom box on the first scan and retain that size for all succeeding scans. Next, be sure that all scans are oriented the same (e.g., flipped, rotated, etc.). Be sure all images are enhanced or unenhanced.

After the scanning is complete and planning is started, choose **S**lice. Set the offset for each image correctly and sort the images. Remember, the offset is the slice separation in centimeters.

The scale must be set on all the slices. To do this, select the first slice and choose **S**et scale from the **T**ools menu. Using the "cm" scale on the image or a true anatomical distance measured on the patient.

Finally, to set a common origin, choose **O**rigin and move the cursor to a common point on the first slice such as the tip of "R" or "L" on the image. Choose that point as the origin. Repeat the process on each slice. Once all slices are processed, move the origin to the desired anatomical location on one slice. To set the origin or all the slices, accept the box to move the origin on all slices. This now sets a common origin on all slices at the desired location inside the patient.

CONTOUR ENTRY

To enter a contour slice onto a patient slice, choose Markup then Contour from the main external beam planning window. The screen will appear as shown in Figure 3.9.

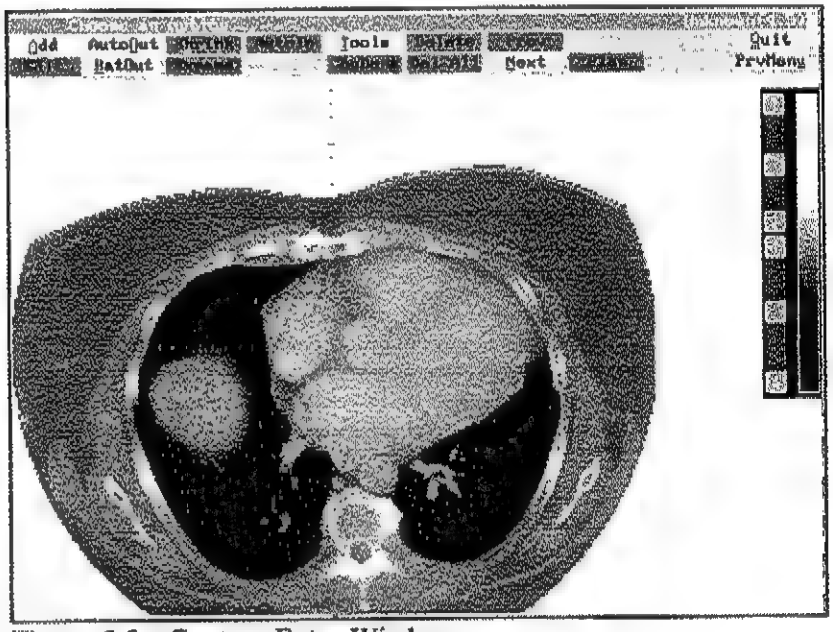


Figure 3.9 - Contour Entry Window

If undesired contours are present, choose either Delete or DelAll to delete them. If a patient slice is needed to store the contour slice, create one in the slices window. Select Add to add a new contour. When prompted, select the entry mode as being the digitizer or mouse. Mouse entry is the default.

Digitizer Entry

In the digitizer entry mode, you are first prompted to digitize the bitpad calibration points U and L. Then, you must either enter the contour magnification factor or the length of a reference line on the contour. If the magnification is not known, digitize the end points of the reference line. See Figure 3.10.

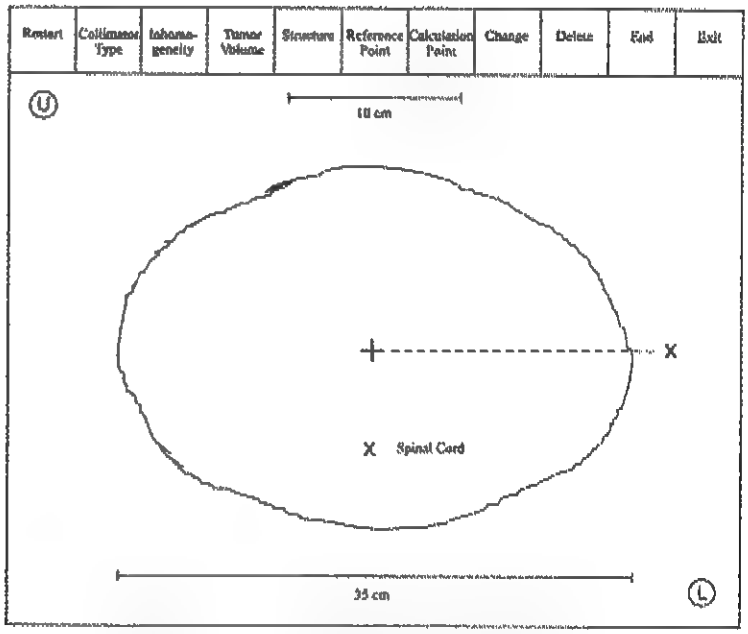


Figure 3.10 - Digitizer Entry of Patient Contours

After digitizing the image origin and a point on the right horizontal axis, begin tracing out the outline of the contour or the point locations. Contours can be entered in either the continuous or point mode. After entry is complete, select **End** to connect the contour back to its starting point and terminate entry. If further contours or points are to be entered, select the type on the digitizer. If no further entry is needed, select **Exit**. If, at any time during the entry process, you need to clear all entries and start over, select **Restart**. If you enter erroneous points, select **Delete** as many times as needed.

Note, that during contour entry, a crosshair cursor appears on the screen which tracks entry. To toggle this cursor between an open-centered mini-crosshair and a full screen crosshair, use the "+" key on the numeric keypad. Note also that a pair of alignment markers track the projection of the cursor onto the coordinate axes.

Mouse Entry Contour or point entry with the mouse functions in a manner analogous to digitizer entry. The same toggling cursor and

tracking marks appear on the screen except under the control of the mouse. No calibration or scaling are required for mouse entry as the on-screen coordinate axes are used for position reference. Contours and points can only be entered in the point mode. Using the mouse and entry type is selected using the on-screen button bar. Note that in mouse mode, by selecting Label, a text label can be attached to the contour slice.

During contour entry with the mouse:
- A left mouse click indicates a new point.
- A right mouse click is used to delete the last point.
- A middle mouse click is used to close a contour. A two-button mouse accomplished a middle click by clicking the right mouse button while the left is depressed.

From the keyboard:
- **Insert** can be used to add the current mouse location.
- **Delete** to delete the last point.
- **End** to close a contour
- **ESC**ape to terminate entry.

Auto Contour Entry

If there are image slices entered for the current patient, then in addition to Add, some combination of the following options will be enabled.

AutoOut: Automatic outside contouring is enabled if there is an uncontoured image slice and it is the current image slice. Selecting this option initiates a threshold based image analysis process which sets an adjustable threshold for the part of the image to be contoured. All image pixels which are not be contoured are turned to blue on the screen. See Figure 3.11.

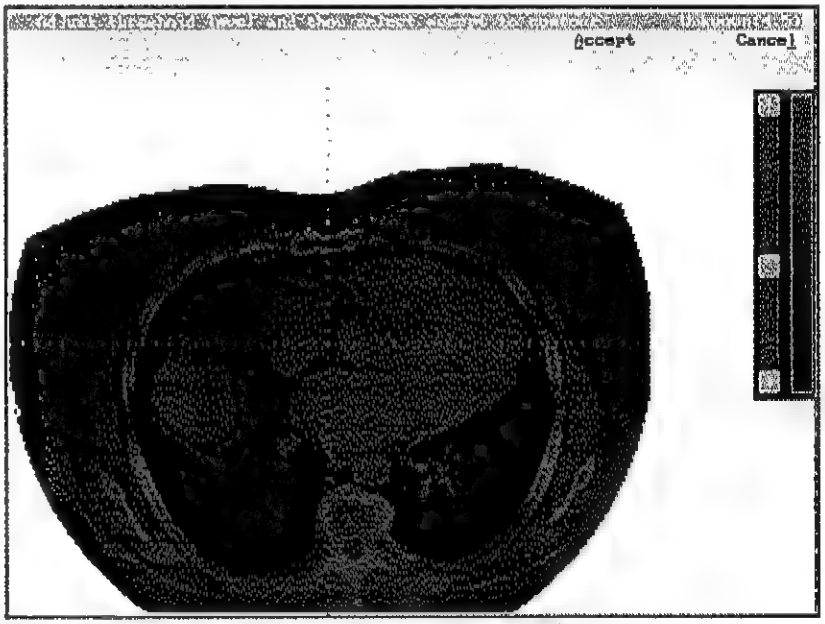


Figure 3.11 - Auto Outside Contour Entry Window

The contouring threshold is indicated on the threshold bar on the right side of the screen. There are several ways to modify the threshold. Click on the up/down arrows at the top/bottom of the threshold bar. Click and drag the threshold button in the threshold bar. Press the up/down arrow on the keyboard or, for coarse adjustment, set the increment using the "+/-" keys on the keyboard and change the threshold with the Shift-up arrow and Shift-down arrow.

Some adjustment of the image threshold may be required before contouring and the threshold should be set such that the entire patient is turned blue, but there is no connection to any blue object in the background. Some practice will be required to use this tool most effectively. Select Accept to draw the contour or Cancel to abort the process.

BatOut: Batch automatic outside contouring is enabled if there are multiple uncontoured image slices. This option works in a manner identical to AutoOut up until Accept is calculated. At this point, instead of contouring the current slice, the current threshold is used to contour all slices for this patient. If you select BatOut and there are existing contours, you will be prompted on how to handle this case. The process can be aborted. All existing contours can be

overwritten or retained. The default option is to prompt for each existing contour as it is encountered.

AutoIn: Automatic inside contouring is enabled if the current slice has an entered outside contour. After selecting AutoIn, you must specify the type of internal contour from the button bar and then the same image analysis process is repeated as for AutoOut. Adjust the threshold until the structure of interest is either entirely blue or entirely not blue and is not connected to some other structure in the same condition. Select Accept when the threshold is correct and you will be prompted to click on the structure of interest. Best results are obtained by clicking near to the edge of the structure and far from complication structures. For example, see Figure 3.12 below.

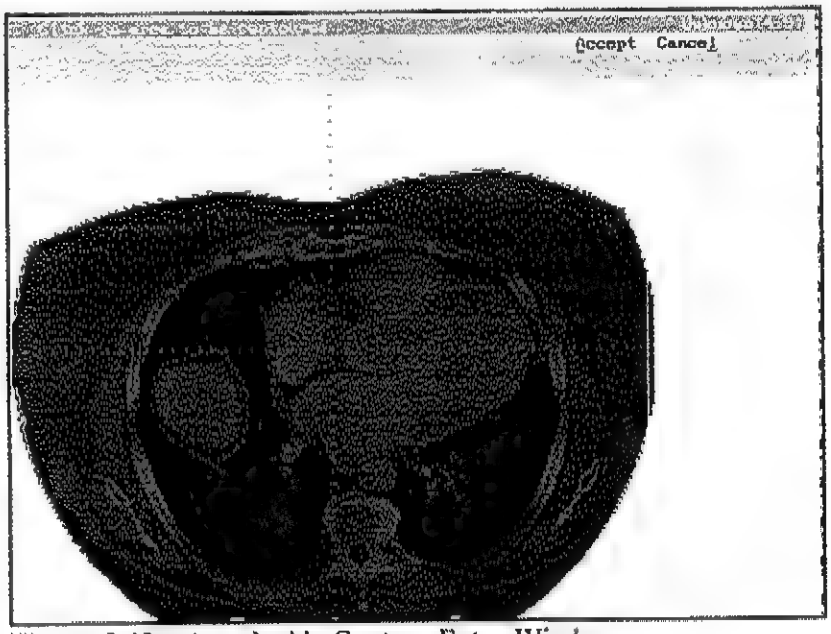


Figure 3.12 - Auto Inside Contour Entry Window

In this example, a region of liver appears inside a region of lung. To contour the liver, click inside it or near to its edge. To contour the lung, click closer to the edge of the lung than to the liver. After the contour has been drawn, you may Accept it or Cancel and try again.

Shrink: The outside contour shrink option is enabled if an outside contour has been entered on the current patient slice. It uses the

same thresholding technique described above except instead of drawing around the blue patient, it shrinks an existing contour down to the threshold.

Expand: The inside contour expand option is enabled if an outside contour has been entered on the current patient slice. It uses the same thresholding technique described above except instead of drawing around a blue or not-blue structure, it expands an existing contour out to the threshold.

Contour Editing

Any contour which has been entered by any means can be edited using the mouse. The Edit option from Figure 3.__ becomes active if any contours have been entered for the current patient slice. After this option has been selected, a box is drawn around the outside contour. Use Next and Prev to step the box through each entered contour until the contour to be edited is indicated. Choosing Accept causes the selected contour to change color indicating that it is editable.

Click the mouse at one end point of region of the contour to be modified. A small circular marker appears on the contour and as you move the mouse around the contour, the selected region of the contour changes color. A second mouse click removes the undesired segment of the contour and begins the contour mouse entry mode. Enter contour points and terminate with a middle mouse click.

Contour Management

The Prev and Next options are available in the window of Figure 3.13 as well as most other windows whenever multiple patient slices exist. These buttons allow you to step back and forth between the slices.

The ChgDens option is available when heterogeneities or calculation points have been entered. This option is used to modify calculation points and heterogeneity names and heterogeneity densities. Heterogeneity names and densities are prompted for at the time of entry, but this option is required for specifying calculation point names.

Selecting Tools opens the window shown in Figure 3.13. This option provides a group of image slice and contour slice utilities.

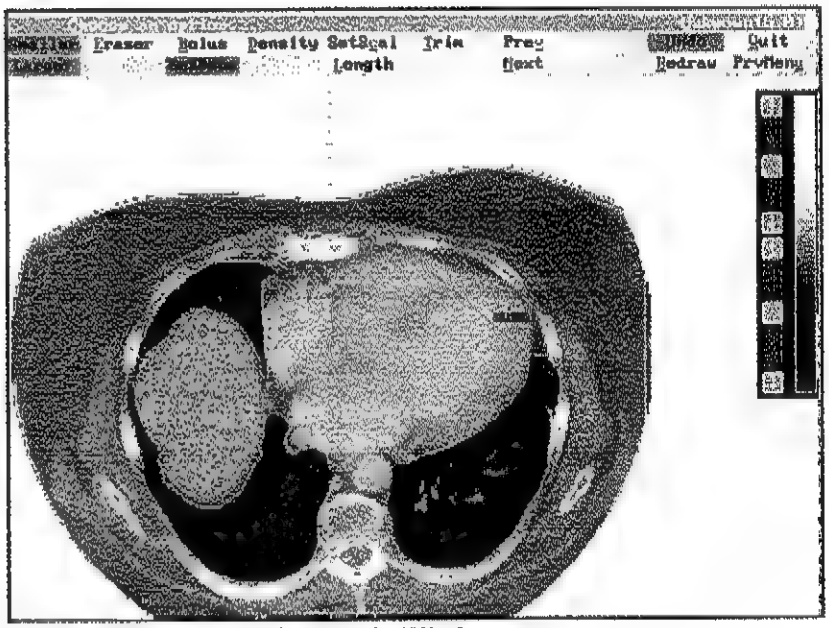


Figure 3.13 - Contouring Tools Window

Length is used to measure the distance between two points. This measurement can be attached to the contour. In Figure 3.8, a length measurement between the medial and lateral breast margins has been attached to the contour slice.

SetScal is used to rescale a contour slice. This option is generally needed only where contours are drawn over film scanned images. Selecting this option prompts for entry of two vertically displaced points separated by a known distance, that distance, two horizontally displaced points separated by a known distance, and that distance. Since the horizontal and vertical scales are frequently the same, the option is provided to copy the vertical scale to horizontal.

EXTERNAL BEAM PLANNING

GENERAL

The External Beam Calculation module calculates the dose distribution resulting on a set of patient slices from a set of teletherapy beams.

This chapter builds on the patient contour information described in the previous chapter. We will describe the techniques for creating an external beam treatment plan, calculating the dose distribution, and calculating machine settings.

As many as 20 beams from different machines may be entered into a single plan in any combination of isocentric, SSD, or rotational. The results of all plans may be stored for later retrieval.

Rotational calculations are performed by integrating over stationary isocentric fields. The default increment is 10 degrees with a minimum of six increments for each integration of a rotational field. The increment can be changed during the planning process.

Reference points and calculation points are specified during patient entry. The dose at each calculation point is explicitly calculated and printed on the summary sheet. Additionally, the dose contribution of each beam to the calculation point is calculated.

All of the slices with at least an outside contour are available for planning. Planning starts with the active slice or the last slice used for the last plan.

EXTERNAL BEAM PLANNING AND CALCULATING

From the main External Beam Planning Menu, the Plan menu option only becomes available when a contour has been entered. If a plan has already been entered for this patient, this plan is recalled. To clear the existing plan, select NewPlan from the Main Menu. If a saved plan is desired, select File, then retrieve the appropriate plan.

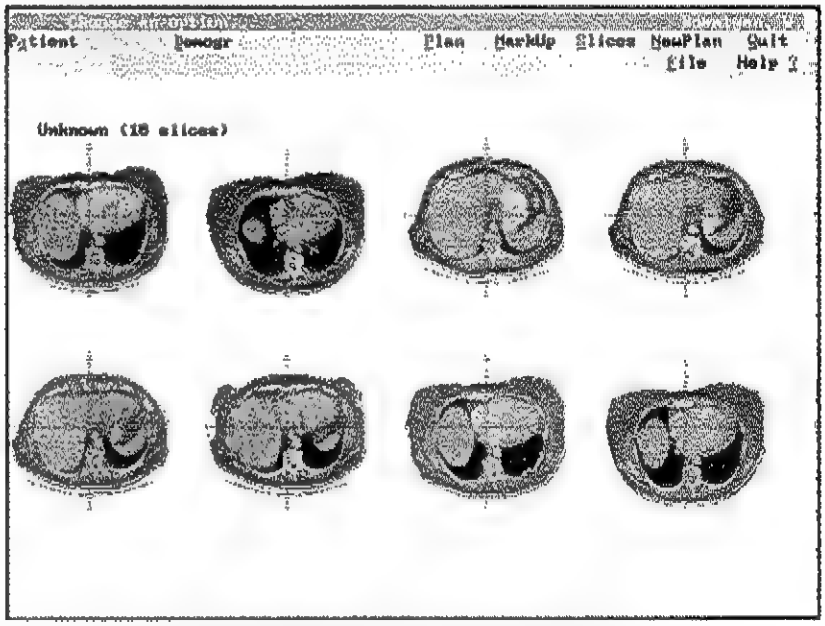


Figure 4.1 - Main External Beam Planning Window

Once the planning phase is entered, only those slices with an external patient contour will be available.

To start a new plan, choose Beam and select a new beam.

NEW BEAM ENTRY

Choosing Beam on the Main External Beam Planning menu brings up a pop-up window requesting beam selection information as shown in Figure 4.2. Select a machine from the list of machines.

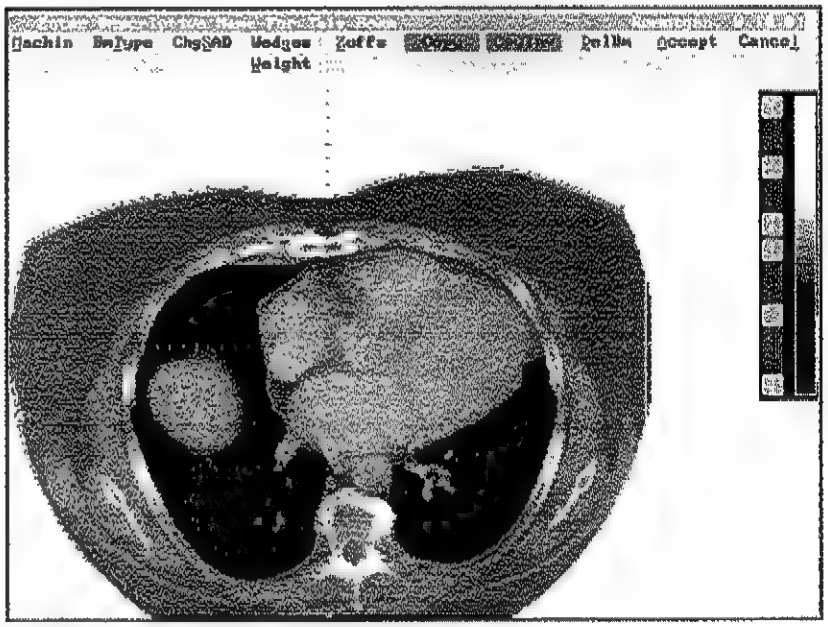


Figure 4.2 - Beam Entry Window

To define the beam, enter all of the information requested in the window. The arrow keys or the mouse allow editing of any entry. You must enter at least the effective field width and effective length (or delete the beam). Choosing Accept accepts the beam. All entries may be edited later.

If more than one beam is already present in the plan, a beam may be copied by selecting Copy. CopyInv copies the mirror image of any previously entered beam. Be sure to enter a unique name for each of the new beams.

If the default type of beam is not correct, it may be changed by selecting BmType.

Machine Selection

Choose Machin from the new beam window to display a listing of the available machines. Use the arrow keys or the mouse to select a different machine. Select the machine by pressing Enter or exit with no change by pressing ESCape. If you are changing from one machine to another, verify that there is correspondence in block type, number, and wedge number between the machine. The two machines may have different block numbers.

Beam Type Selection

Choose BmType to change the type of beam. The beam type may be Isocentric, Rotation, or SSD. Use the arrow keys or mouse to select the type and press Enter or press ESCape to exit without any change. An SSD beam is a special case of an isocentric beam with the isocenter on the skin surface.

Beam Deletion

A beam may be deleted in two ways. The easiest is to choose Beam which gives a list of the present beams along with the capability to add a new beam. Use the arrow keys or mouse to select the beam number to delete. Press the Delete key from the keyboard and confirm with a Yes. The other way to delete a beam is to select the beam from the list of beams, then choose DelBm.

Beam Size Selection

Beam size is specified by entering the collimator width and length along with the effective width and length. Effective size is the blocked beam size that is projected onto the patient, whereas, collimator size is the actual setting of the machine collimator. The effective size is always less than or equal to the collimator size. Specifying effective field size (equivalent square) is one method to allow for custom cast blocking of the field which reduces the effective size of a field. From the beam's eye view, the program will automatically calculate the effective field size if blocks are entered.

The collimator field size is that field size set on the treatment unit and the effective field size is the blocked field size seen by the patient. Both are projected to the nominal SSD or SAD for that treatment machine. The effective field size is used to look up the TMR for the calculation. The collimator field size is used to determine the OCR and output factor for the beam. The output factor is corrected for blocking by using the Peak Scatter Factor of the effective field size.

If the collimator field size entered is outside the bonds of the OCR data, it is set to a field size that is just inside its maximum or minimum limits. It is important that you know what the range of maximum and minimum field sizes are in each data file. If the beam is an electron beam, it must be specified as an SSD beam. Rotating and isocentric electron beams are not supported.

Beam Weighting

To specify the weight of a beam, specify the weight point, total weight value, and the number of fractions. The weight point can be the isocenter of the beam if it is an isocentric beam, point of dose maximum (d_{max}) on the central axis, monitor units, or a calculation point. Isocenter and d_{max} points are defined on the central axis slice only. If you weight to a calculation point, it can be any calculation point defined on any slice as long as that point is inside the beam. The weight is the total dose in cGy to be delivered by that beam to the weight point. The number of treatment fractions can be entered.

Remember, normalization and prescription may change the actual machine settings. Therefore, the weights can also be relative. For sets of isocentric fields, it is generally preferable for beam weight to be chosen in such a way that they sum to 100.

The weights of all beams entered may be changed by choosing AllWt. Selecting this option shows a window as shown in Figure 4.3 with the weights of all the beams. Using the keyboard, you may edit any weight value. NextBm and PrevBm or the arrow keys can be used to move around the table. Accept or Exit can be used to terminate entry with or without saving.

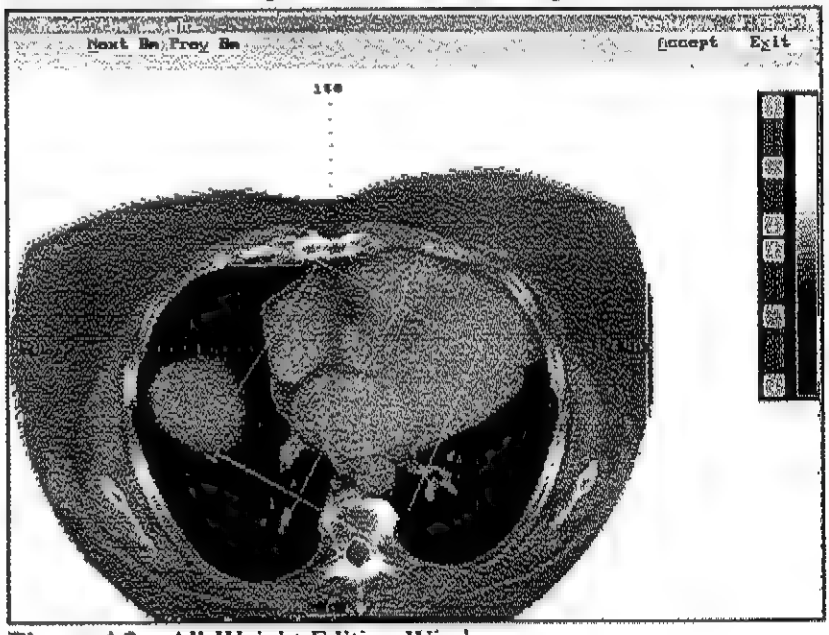


Figure 4.3 - All Weight Editing Window

Beam Acceptance

After all the beam descriptions have been entered, accept the beam by selecting Accept. If this beam is not desired, press ESCape to reject the beam. The beam, once accepted, becomes the active beam.

ALTERING BEAMS

Once a beam has been entered, the planning menu is updated as shown in Figure 4.4. The beam may be moved or changed by this new set of functions.

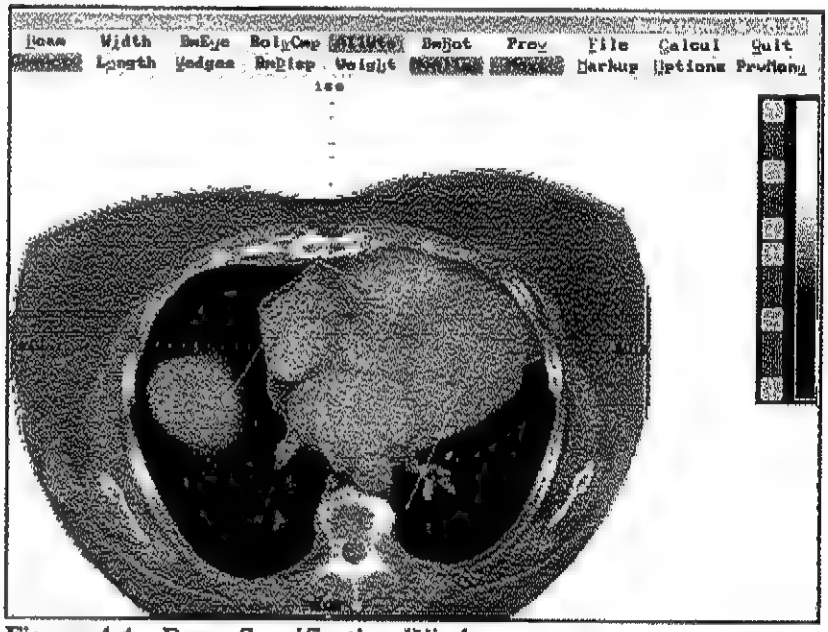


Figure 4.4 - Beam Specification Window

BEAM DESCRIPTION

There are three different types of beams available for planning: SSD, isocentric, and rotating. These beam types are presented differently on the screen as shown below.

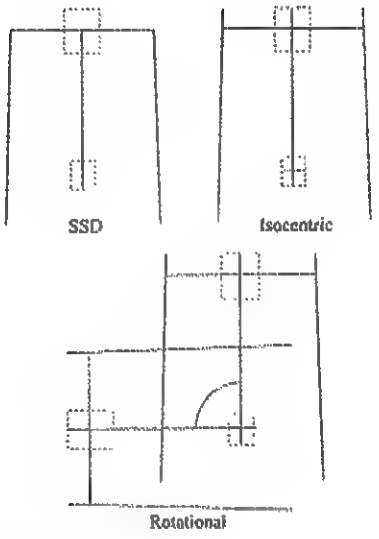


Figure 4.5 - Beam Icons

SSD Beam The two boxes indicated by dashed lines are not seen on the screen, but indicate "hot" regions on the beam icon which can be grabbed by clicking on them with the mouse. The top one allows positioning of the beam with the mouse and the bottom one allows rotation of the beam with the mouse. The middle vertical line indicates the central axis of the beam and the peripheral lines indicate the diverging beam edges. Where the lateral line crosses the central axis is at the beam nominal SSD point.

Isocentric Beam An isocentric beam differs from an SSD beam in that the bottom hot region now indicates the beam isocenter and is used for positioning. Thus, the top hot region is used for rotation.

Rotational Beam A rotational beam's icon is presented as a pair of isocentric beams with a common isocenter connected by an arc through which the beam rotates. A rotational beam has two rotation hot regions used for specifying the initial and final gantry angles.

Beam Modifiers

A beam which is modified by a wedge has the wedge indicated on its beam icon. There are four types of wedges available. These are the: Open Beam, Standard Wedge, Split Field, and Split Wedge. The Open Beam is indicated as shown in Figure 4.6.

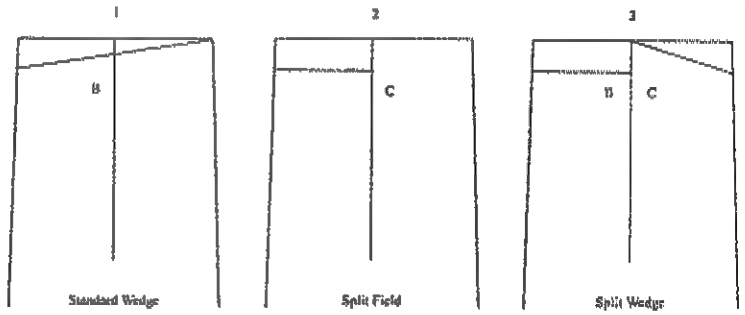


Figure 4.6 - Wedge Icons

Presentation of wedges on beam icons would be the same for isocentric beams. For rotational beams, the wedges presented only at the initial angle.

If a bolus and/or compensator are present, this is indicated by a "B" and/or on the beam icon just below the wedge region as shown in Figure 4.6.

MOVING BEAMS

Move a Beam with the Mouse

The mouse may be used to move a beam. To move the beam, move the mouse pointer to the hot region, click the left button, and hold the button down. The beam can now be moved. Let up on the left button again to fix the beam. An SSD beam will automatically attach itself to the contour. The coordinates of the beam appear in the status bar during movement. To rotate the beam, click on the hot region and move the mouse left and right. Release the button to fix the angle. The angle of the beam appears on the status bar during rotation. For rotational beams, both the initial and final angles may be fixed.

Move all Isocentric Beams with the Mouse

To move all isocentric beams, click MvAlIso and activate a large crosshair on the screen. Move the crosshair to the new isocenter. Release the button and all isocentric beams move the same offset

as the active beam. If all beams have the same isocenter, then they will all move together.

Moving a Beam with Keyboard

In addition to the movements and changes that may be made with the mouse, an isocentric or rotational beam may be repositioned using the arrow keys. SSD beams are moved around the outline. The angle of a beam may be changed from the keyboard by selecting BmRot and a new menu appears as shown in Figure 4.7.

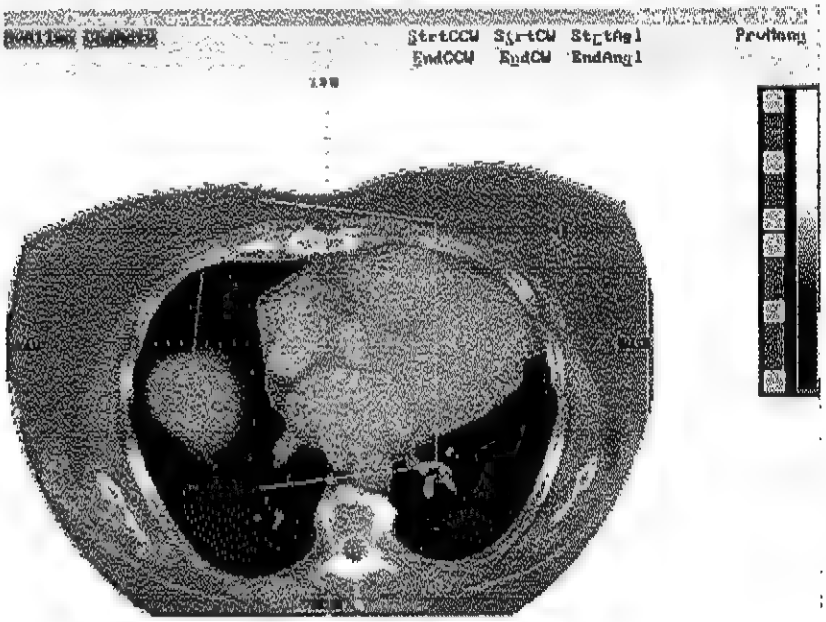


Figure 4.7 - Beam Rotation Windows

For the case of a fixed beam, StrtCCW/EndCCW would be replaced by RotCCW; StrtCw/EndCw would be replaced by RotCW; and StrtAgl/EndAngl would be replaced by ChgAngl.

The default step increment for changes in position and angle is 1 cm and 10 degrees. This may be changed by using the + or - keys. + increases the increment and - reduces the increment by a factor of 2. ChgAngl which allows entry of a gantry angle from the keyboard.

EXTENDED SAD

It is sometimes useful to specify an isocenter for a patient's treatment independently of that specified for the treatment

machine. To do this, choose Beam from the root external beam menu to specify the beam to be changed. Then choose ChgSAD to redefine isocenter. Return to save the value and return again to save the beam. Since Prowess uses the same calculation approach for SSD and SAD beams, this is equally applicable to SSD treatments. Note that redefining a treatment SAD does not change the treatment machine calibration, machine data, or collimator calibration. Thus, beam dimensions are scaled and inverse square corrections are made between the machine isocenter and beam isocenter.

CHANGING ACTIVE BEAMS

After entering several beams, you often want to change one of the previously entered beams. Use the Page Up and Page Down keys to move to one of the other beams or choose CngActv to increment the active beam. Notice the display changes to the new active beam after this button is pressed.

To enter another beam, choose Beam. You must enter all of the information or copy the beam as described in the section New Beam Entry. You will note that the active beam is denoted by the long geometric edges displayed in green as well as the T bar, whereas, the inactive beams are denoted by a T bar only and is shown in white.

MULTI-SLICE CALCULATIONS

When the Calcul option is selected, the plan is calculated on all slices which have at least the outside contours entered. Single-slice calculations can be selected by choosing Option, then MPlane, and set it to "No" causing only the active slice to be calculated.

Multi-Slice calculation first calculates the weight for a particular beam, then the dose to all the slices from that beam. The process is repeated for all of the beams. The calculation is done by using the difference in the Z-offset of each slice in relation to the central axis slice Z-offset. For a beam on a slice at 50.0 cm, the calculation on a slice at 53.0 cm would have an offset of 3 cm from the central axis.

COMPOSITE PLANS

When calculating a composite plan, you may have a patient contour and multiple sets of beams each of which has been (or will be) treated with a specified number of monitor units for a specified

number of days. Each beam is weighted to monitor units and assigned a weight equal to the total number of monitor units administered through the beam. In this case, one fraction is entered. The plan is then calculated and the resulting isodose distribution has units of total dose in cGy.

Another case which is sometimes referred to as composite planning is the case when not every beam is treated every day. For example, suppose one is treating with an isocentric opposed pair and using wedges every other day. Four beams are actually treated whose weights add to 100%. The plan calculated is actually an integral plan over a two-day period. Thus, the prescribed dose entered must also reflect a two-day period (twice the fraction dose). If only a single fraction dose were entered, the monitor units calculated would be half that desired.

BEAMS EYE VIEW

The active beam can be viewed in a transverse projection as though you are looking down the beam. This projection is called the Beams Eye View (BEV). Choosing BmEye produces a pop-up window showing the BEV. In this projection, the collimator is shown as well as blocks and wedges. See Figure 4.8.

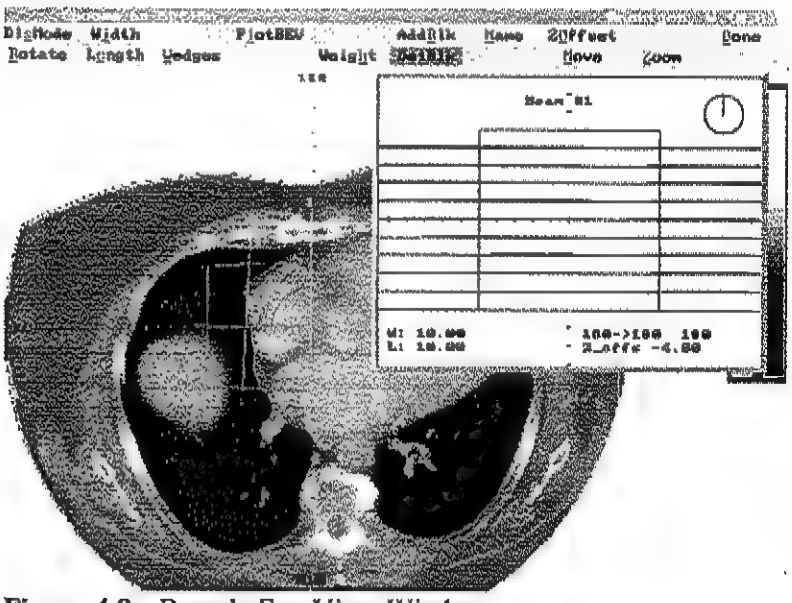


Figure 4.8 - Beam's Eye View Window

Blocks can be entered using the mouse or the digitizer. To enter a block, choose AddBlk, specify the type, then use the mouse or digitizer. Enter the desired block. Close the block by choosing the digitizer End menu item or hold the left mouse button while clicking the right button. The block will appear as a closed contour which is shaded red.

Delete any block by choosing DelBlk. Select the desired block by rotating through Prev/Next until the desired block is found. Choose Accept and that block is deleted.

The location of the BEV window can be moved into any of the four quadrants by selecting Move. To enlarge the window, select Zoom. To return to the small window, reselect Zoom.

The primary slice for the active beam can be changed by selecting ZOffs. Once selected, a list of the available slices is shown on the screen. Click on the desired slice. The screen is updated with the new center slices.

All patient contour projections are shown in the beam's eye view. To view the contour projection through a rotating beam, select

Rotate. Gantry angle is tracked by the clock icon in the upper right corner of the BEV window.

Exit the Beams Eye View by choosing Done to return to the normal planning display. If blocks or a wedge have been entered, then a cross section of the block/wedge will appear on the beam.

BEAM DISPLAY

A text description of the beams on the screen can be shown by selecting BmDisp. The information describing beams which have been entered for the plan are displayed at the bottom of the screen. The active beam is shown in green, the others in blue. Each beam is described by its number, machine type, its X and Y position in centimeters with respect to the origin, angle in degrees, wedge number, collimator width and length in centimeters, and weight. The weight is shown as the dose to a specific point shown in parentheses, where (0) is the isocenter, (-1) is the dose at d_{max} and (-2) is weight to monitor units. As the beams are changed, the parameters displayed on the bottom of the screen are continuously updated.

ADDITIONAL FUNCTIONS

There are a number of additional functions which are available by selecting Options. Choosing this item produces a new set of functions allowing you to change the matrix size, turn on and off heterogeneity correction during calculation, change contour names and densities, change the calculation window, and change the display window.

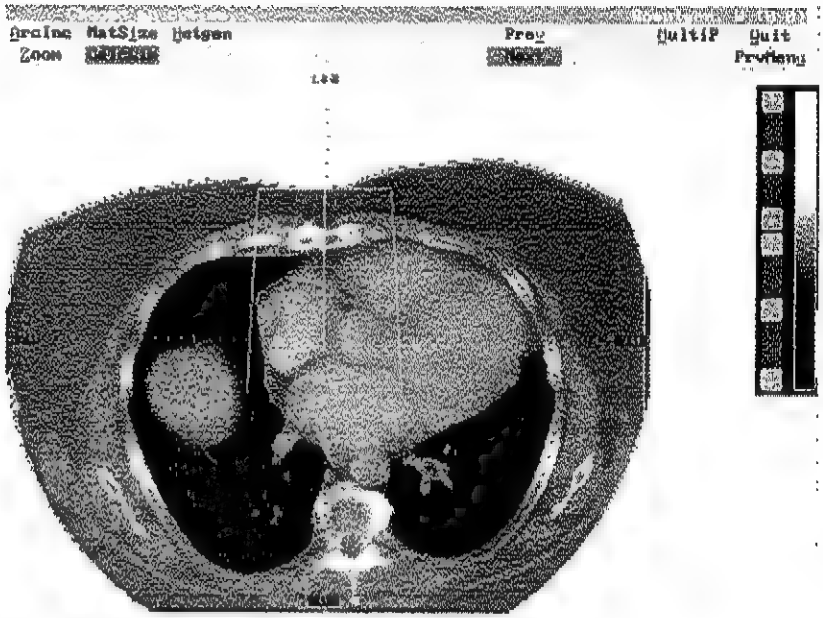


Figure 4.9 - External Beam Options Window

Choosing ArcInc and MatSize requires entry of a numeric value. ArcInc allows the change of the arc increment of the gantry angle for rotating beams. MatSize allows selection of a matrix size for calculation. 1024 is the default. The maximum matrix size is 16,384.

By selecting Hetgen, heterogeneity corrections can be enabled or disabled. Select "Yes" or "No" and ESCape to exit Prowess.

Supports three heterogeneity models: Effective path length, equivalent TMR, and the Batho power law. Only one model is supported at a time. The model chosen is selected in the control file and this selection should be made by the responsible physicist.

Multi-Slice calculations can be enabled or disabled using the MPlane option. By default, the option is enabled, but may be changed by choosing "No". If disabled, only the active slice will be calculated.

WEIGHTING

Each beam must have an associated weight and weighting method. One way to weight a beam is by monitor units. When a beam is weighted to monitor units, its weight indicates the number of monitor units to be delivered.

Another way to weight a beam is by the dose it delivers to a point. The point must be specified. If the weight point is specified as d_{max}, then (for a stationary beam) this is equivalent to weighting by given doses with blocking and wedges in the beam on the central slice. For example, if a pair of beams are weighted to d_{max} and assigned equal weights, they will deliver equal doses to their respective d_{max} points. A beam that is weighted to d_{max} and has a bolus chooses the d_{max} depth inside the patient contour, not at d_{max} from the bolus surface.

A beam can also be weighted to isocenter. In this case, the weight values specifies the dose contribution from a beam to isocenter. Alternately, it can be weighted according to its contribution to a user specified calculation point. This option is useful when a beam is blocked at or near midline. Any calculation point on any slice can be used as a weight point.

When specifying a weight point, ensure that the point is not under or near a block, outside the beam or outside the patient.

BEAM CALCULATION

To calculate the external beam plan, select Calcul. During calculation, the beam number, its angle, and the slice being calculated are shown. The calculation may be stopped by pressing the **ESC**ape key.

The algorithms used to calculate this plan depend upon the options selected in the system control file. These options are shown on the printed hardcopy for reference. They cannot be changed within the program.

THE FINAL PLAN

Following calculation, the screen shows the completed plan. The isodose curves may be displayed by selecting the desired values from the pop-up window. Edit or enter new values as desired. **ESC**ape completes isodose entry and shows the window shown in Figure 4.10.

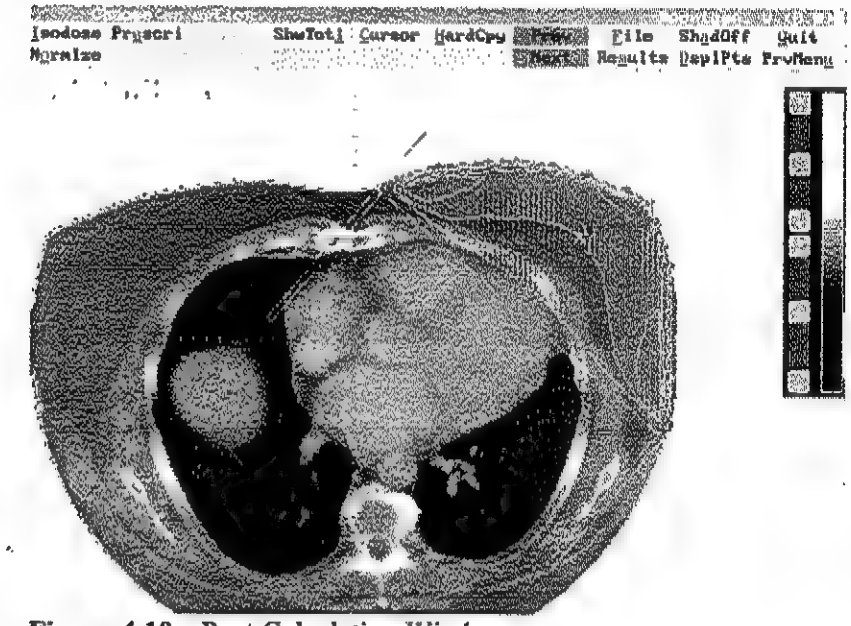


Figure 4.10 - Post Calculation Window

Normalization

The calculated dose distribution can be normalized. There are five different ways the plan can be normalized. By selecting Normlze, the default normalization is displayed. The default can be changed in the program control file. Typically, normalization to the isocenter or unnormalized is used as the default. When the Normlze option is selected, the following menu items appear on the screen:

Point - Normalizes to any valid calculation point in any slice.
IsoCntr - Normalizes to the isocenter if there is at least one isocentric beam. If more than one isocentric beam is defined, it normalizes to the isocenter of the first beam.
Max - Normalizes to the maximum dose in the dose matrix.
Line - Assigns the dose specified to the line specified.
Unnorm - Unnormalizes the dose distribution.

Prescription

Before printing, plotting, or examining the results; a prescription must be entered. Select Prescri to enter the prescription. The dose and the isodose line to which the dose is specified. The prescription applies to the dose as displayed on the screen. The default prescription is 100 cGy to the 100% dose line.

Display Points To view the dose to the calculation points, choose DisplPts. The dose to the points of calculation are displayed on the screen in a window. The contribution to each point from each beam is not displayed, but is shown on the printout.

Cursor Choosing Cursor after calculating displays the dose to any point inside the patient external contour. When the function becomes active, a cursor is displayed, controlled by the mouse. Its position is displayed at the top of the screen. When the cursor is positioned at the desired location, press Enter or click the left mouse button to obtain the dose at that point.

Exit the cursor mode by selecting Done or use the ESCape key.

Results The summary of the calculated results can be shown by selecting Results. The selection brings up a pop-up window showing all of the beams entered along with the calculation SSD, TMR, output factor, and machine setting for each beam. The printout shows more detailed results. The total dose to the plan can be shown by selecting ShwTotl. This option displays a window with the total dose in cGy for each isodose line.

File To save or retrieve a completed plan, select File. Selecting this option allows you to save or retrieve a completed or partially completed plan. You may also list the saved plans or delete a plan. Choose the option you desire from the pop-up window. If you decide to save the current plan be sure to give it a unique and descriptive name.

Warning: Be sure a hand calculation is done to verify the monitor units calculated by the computer. Should the hand calculations differ by more than 2%, *Do not* implement the plan until the problem has been resolved.

Hardcopy The printed copy activated by Hardcopy is discussed in the next chapter. The printout and the color plot should be kept in the patient's chart as a permanent record.

SUMMARY OF BEAM FUNCTION

AddBlk: Allows entry of a block using the mouse or the digitizer.

AdLabl: Allows entry of a label on the active beam.

AllWts: Activate a large window showing the weights of all the beams. You may edit the total weight, weight per fraction, number of fraction, type, and weight point of each beam. **ESC**ape exits this option.

Beam: Function used to add a new beam to the plan or change the treatment machine, beam type, or delete an old beam. If you wish to edit an old beam, then select the old beam number with the arrow keys and press **Enter.**

BlsCmp: Bolus or compensator material may be added to a beam using this selection. Specify the thickness of tissue equivalent material on the central axis using this selection. SSD's which are reported on the dose calculation are to the skin for an SSD setup and to the bolus on an isocentric setup.

BmDisp: Displays the beam parameters in a window at the bottom of the screen.

BmEye: This function displays the Beams Eye View (BEV) for the active beam. Blocks may be added and deleted and the field size changed from within this window. The following functions are available with the BEV active.

BmRot: Provides a menu to rotate a beam from the keyboard.

Calcul: Calculates the dose distribution for the beams entered on the plan with/without correction for inhomogeneities.

ClAngl: Changes the collimator angle by keyboard entry.

CngActv: Increments the active beam to the next beam.

CngAngl: Changes the beam angle to an absolute value by entering the specific beam angle in degrees.

Cursor: Puts a cross on the screen which may be moved by the mouse. Once a position is located, press enter or click with the mouse and the dose at the cursor point is displayed. The cursor may be moved again and the procedure repeated. Once the doses

have been determined, select Done to go to the completed plan display. The cursor may be saved as a calculation point by using SavePt. Enter the name of the calculation point and the point is saved. This point may be used as a weight or normalization point just like any other point.

DelBlk: Deletes a block or label.

DisplPts: Displays the dose to the points of calculation.

EndAngl: Changes the rotating beam end angle by entering the specific angle in degrees, from the keyboard.

EndCCW: Rotates the end angle of the rotating beam one step counter-clockwise about the isocenter.

EndCW: Rotates the end angle of the rotating beam one step clockwise about the isocenter.

File: Allows you to save and retrieve complete or partial plans.

HardCpy: Produces a new menu to allow production of hardcopy of the plan. Details of this menu item are discussed in the next chapter.

ImagPrt: Prints the contours and isodose curves superimposed on the CT image.

Isocntr: Normalizes to the isocenter.

Isodose: Displays the pop-up for choosing isodose values.

Length: Changes the beam length in centimeters.

Line: Normalizes to an isodose line.

Max: Normalizes to the hot spot.

Move: Causes the BEV window to move to one of four quadrants.

MvAllso: Moves the isocenter of all beams to a new position.

Name: Changes the name of the center beam.

Normlze: Changes plan normalization values and types.

Options: Produces a new subset of functions to be changed which include Arc Increment, Matrix Size, Heterogeneities On/Off during calculation, Change Contour limits, Change Contour density and Adjust the Scale of the Screen Display, and change offset.

Plot: Plots the contours and isodose curves on the plotter. (Select the paper size and orientation.) If at any time during the plotting the process needs to be halted, press the ESCape key and control is reverted back to the program.

Point: Normalizes to a defined calculation point.

Prescri: Entry of prescription dose and isodose line.

Print: Prints a summary of the plan and calculates the machine settings needed to carry out this plan. Be sure all beam descriptions are accurate as they may effect the monitor unit calculation.

Prt/Plt: Prints and plots hard copy as described above.

Quit: Halts the planning and erases all data that has not been saved. Confirm your EXIT if the plan has not been saved.

Rot CW: Rotates the beam one step clockwise about the SSD point of definition or the isocenter beam.

Rot CCW: Rotates the beam one step counter-clockwise about the SSD point of definition or the isocenter of the beam.

ShwTotl: Displays the total dose and maximum dose for each isodose line on the screen.

StrtAngl: Changes the rotating beam start angle by entering the specific angle in degrees, from the keyboard.

StrtCCW: Rotates the start angle of the rotating beam one step counter-clockwise about the isocenter.

StrtCW: Rotates the start angle of the rotating beam one step clockwise about the isocenter.

Unnorm: Unnormalizes dose distribution (default).

Wedge: Changes the wedge of the beam. When selected, the wedge choices are displayed on the screen. Specify the direction of the wedges as clockwise or counter-clockwise.

Weight: Edits total weight, number of fractions, and weight point for the active beam.

Width: Changes the beam width in centimeters.

ZOffs: Changes the central slice of the beam.

Zoom: Zooms the BEV to full screen.

EXTERNAL BEAM PLAN MANAGEMENT, HARDCOPY, AND SAMPLE PLANS

PLAN MANAGEMENT

After an external beam plan has been entered and calculated, that plan and its calculation results are automatically saved as the active plan. Any modification made during planning is automatically reflected on the active plan. To clear the active plan, select NewPlan from the main external beam planning window.

If you need to enter multiple plans for a single patient, they should be saved independently. The File option may be selected from the main external beam planning window or from the planning window by selecting Plan and then File. By selecting File from the main external beam planning menu, you can present a list of existing plans, retrieve a plan from that list, or delete a plan from that list. By selecting File from the planning window, you may select one of these options or you may add the current plan (if one exists) to the list of saved plans.

All contours and images which have been entered into the patient file are automatically saved. All entered data is assumed to pertain to one patient and all plans are applied to all entered patient data. It is not possible to enter multiple sets of contour or image data into one patient file.

HARDCOPY

After an external beam plan has been entered and calculated, the plan and calculation results should be printed for a permanent record. There are four types of hardcopy results which can be produced during external beam planning. These are the beam's eye view plot, external beam plot, external beam image print, and external beam results print. They are discussed below.

BEV Plot

To plot the beam's eye view of the current beam, select BmEye and then PlotBEV. By selecting ChgActv, this process can be repeated for all beams. The plotted BEV will show the locations of the collimators, the locations of all blocks, and the projection of all contours into the BEV.

External Beam Plot

After an external beam plan has been entered and calculated and a prescription has been entered, the Hardcpy option becomes active. Select Hardcpy to enter the hardcopy window as shown in Figure 5.1.

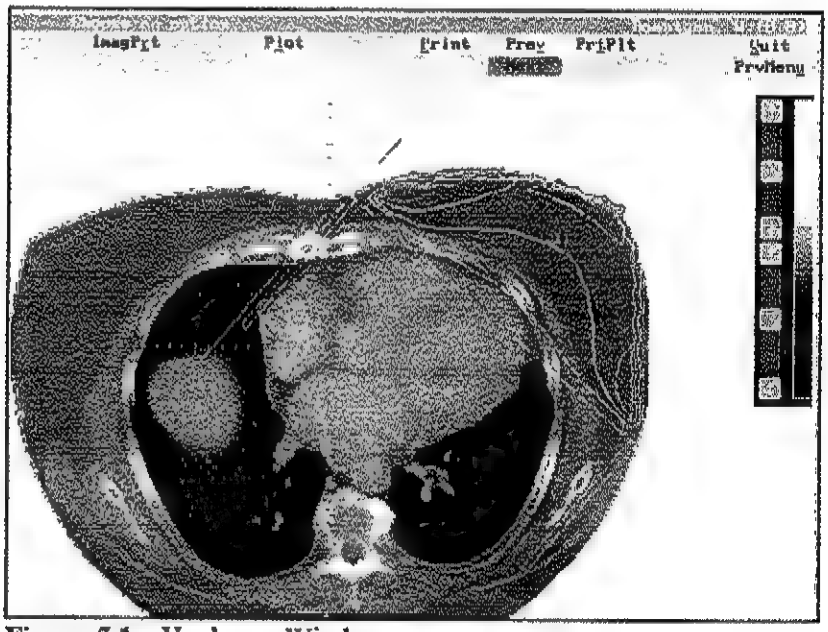


Figure 5.1 - Hardcopy Window

Select Prev and Next to choose the slice you wish to plot. Select Plot and enter the plot title, paper size, orientation, and scale to plot the current slice as shown in Figure 5.2 to plot isodose and contour information.

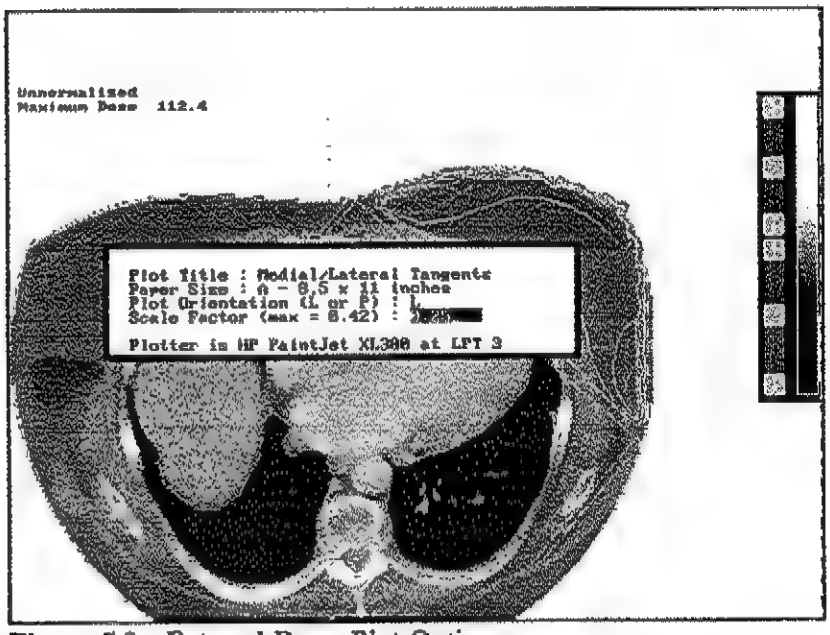


Figure 5.2 - External Beam Plot Options

The two choices of plot orientation are portrait and landscape. These two orientations are demonstrated in Figure 5.3.

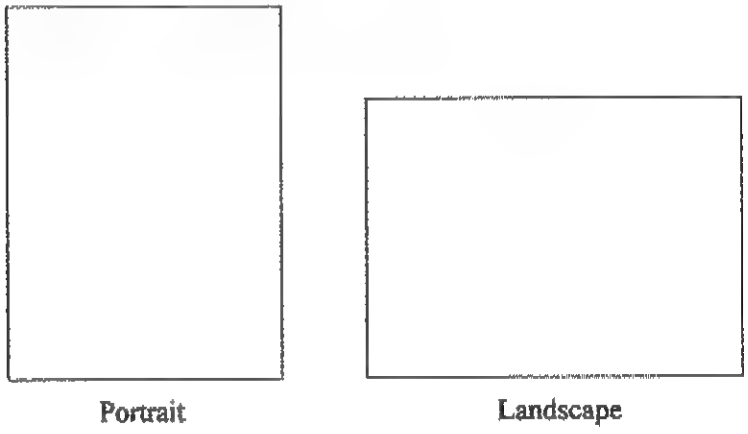


Figure 5.3 - Plot Orientations

Image Print External beam plotting and image printing function almost identically, to generation image print, select ImagPrt from the hardcopy window. The only difference in those hardcopy options is that the image print overlays all isodose and contour information with the grey scale image on the page. Note that the window ane level settings are reflected in the printed image.

Print Selecting the Print option from the hardcopy window causes the complete treatment plan description and calculation results to be printed. Demographic information is printed at the top of the page followed by the prescription data and then a beam listing.

Each beam entry contains a complete beam description, all physics parameters, and calculated machine settings. If entered, calculation point doses and tumor dose statistics will be printed on a second page. Note that all information needed to independently calculate the machine settings are included in the print.

The PrtPlt option is identical to selecting Print and Plot.

DAILY CALCULATIONS

GENERAL

The Daily Calculation program provides options to calculate point doses and machine settings, Nominal Standard Doses (NSDs), and interfield gaps.

After selecting Daily Calculations for the main treatment planning menu, options are presented as shown in Figure 6.1 and described below.

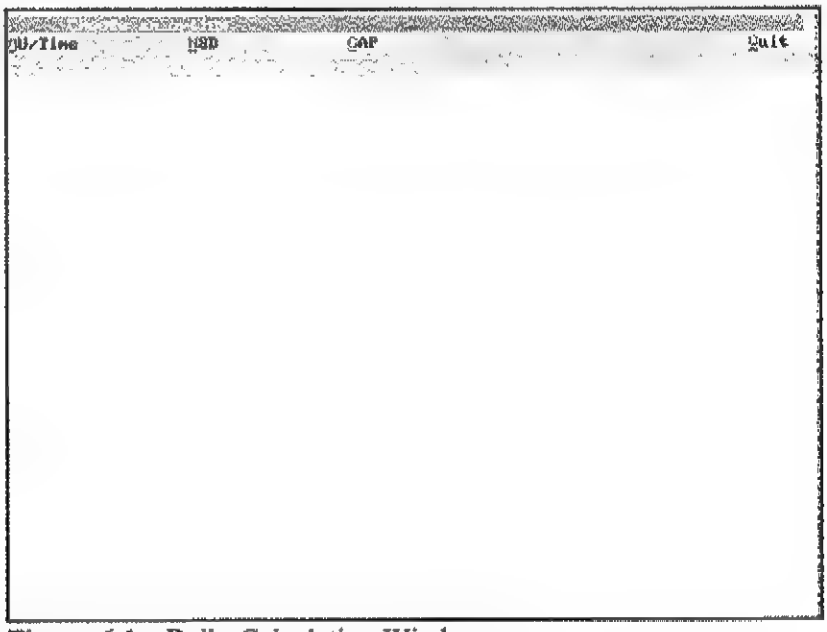


Figure 6.1 - Daily Calculation Window

MACHINE SETTINGS

Selecting the Mu/Time option enables you to calculate the machine setting for a teletherapy beam. The machine setting calculation window is shown in Figure 6.2 and is presented after selecting a machine.

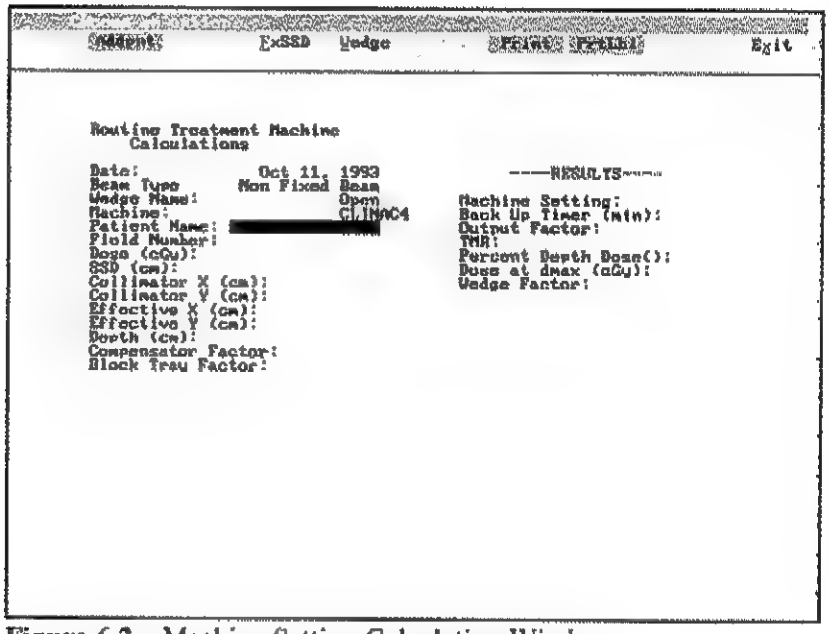


Figure 6.2 - Machine Setting Calculation Window

There are two active buttons on the button bar. The one on the left causes the beam type parameter to rotate through its three values while the button rotates through its three values. Selecting ExSSD sets the beam type to an SSD beam and forces the beam SSD to be the nominal SSD. Selecting ExSAD sets the beam type to an isocentric beam and forces the beam SSD to be the nominal SSD minus the depth. Selecting NoExSAD sets the beam type to non-fixed beam and allows the SSD to be freely specified.

Selecting the Wedge option allows you to select a wedge from a list. Use the keyboard to enter the treatment field parameters shown in the upper left part of the window. After the last parameter is entered, the machine setting results are calculated and presented in the upper right corner of the window. See Figure 6.3

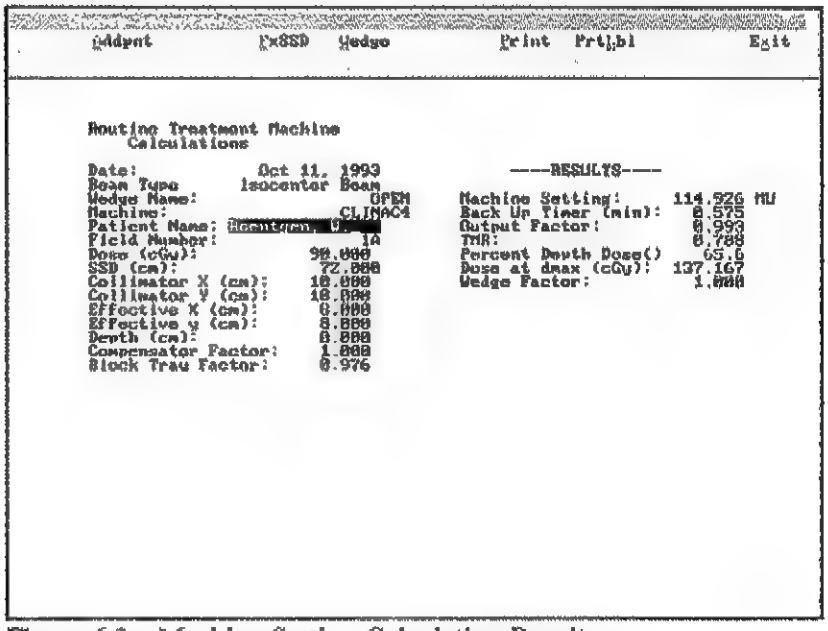


Figure 6.3 - Machine Setting Calculation Results

A note is in order about collimator and effective field size. The collimator field size reflects the jaw settings on the treatment unit. The effective field size reflects the field size seen by the patient with all forms of blocking. This includes secondary blocks and patient flash. The collimator settings are used to look up the machine output factor and the effective field size is used to look up the TMR as well as a PSF correction. Both field sizes are referred to the machine isocenter. An example of a field which has a collimator field size of 10 x 10 and an effective field size of 8 x 8 is shown in Figure 6.4.

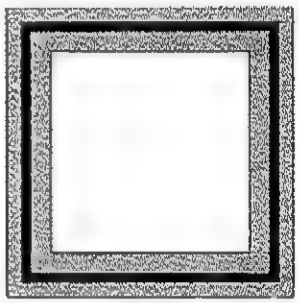


Figure 6.4 - Blocked Treatment Field

After the machine setting is calculated, you have the option of changing any of the treatment parameters. The calculation results will be automatically updated. You have the additional options of Print and PrtLbl to print to a page or to a label. Before printing, you may also choose to enter up to four secondary calculation points using AddPnt. An example is shown in Figure 6.5.

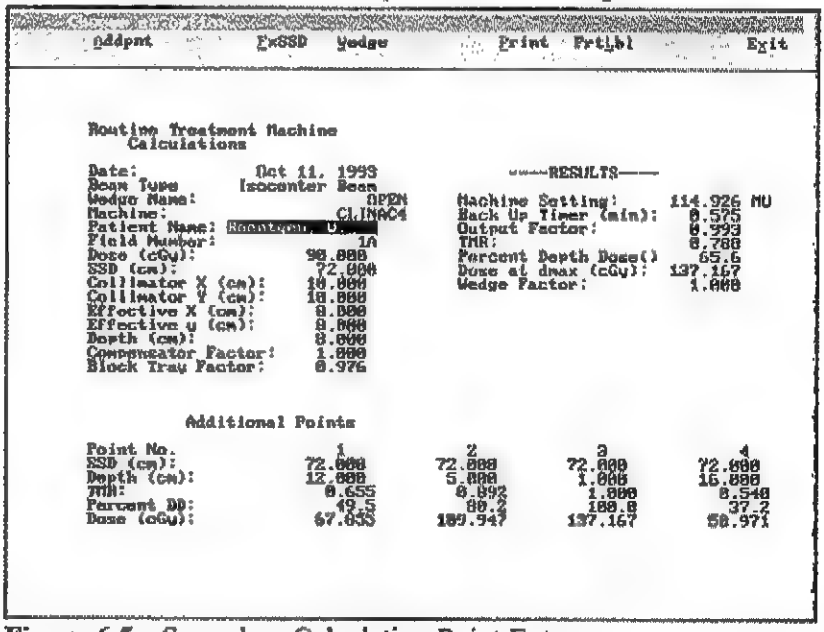


Figure 6.5 - Secondary Calculation Point Entry

NSD CALCULATION

This program performs a single Nominal Standard Dose (NSD) calculation on a patient's treatment. The program uses the standard Ellis (1) formula of:

$$NSD(Ret) = Total\ Dose\ (cGy) * Time^{-0.11}\ (days) * Fraction^{-0.25}$$

Select NSD from the daily calculations menu. A new screen appears as shown below:

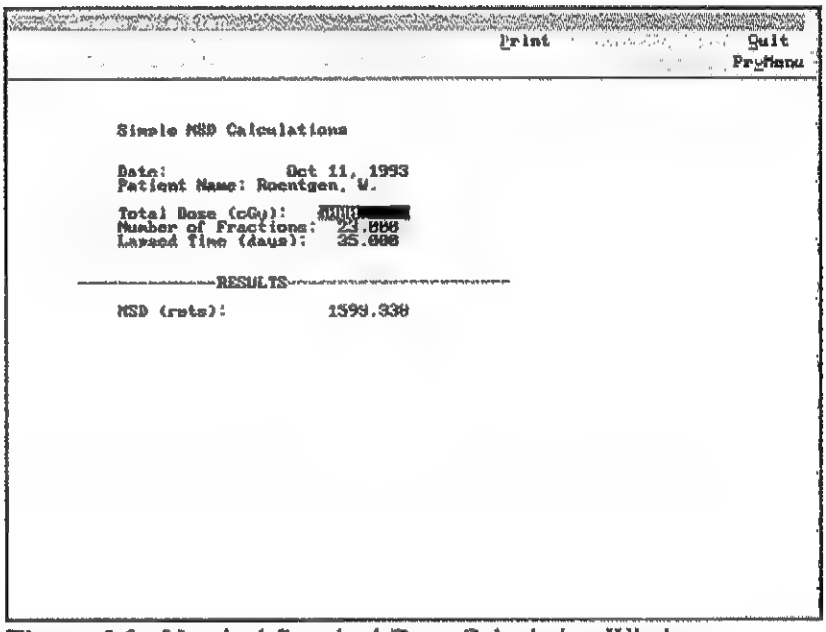


Figure 6.6 - Nominal Standard Dose Calculation Window

Enter all of the information requested on the screen. Once enough information has been entered, the results will be displayed at the bottom of the screen. At this time, the Print menu appears. You may edit any of the items using the arrow keys. The program automatically recalculates the results.

Once the results are satisfactory, print the screen by selecting **P**rint.

End the program by selecting **Q**uit or **ESC**ape from the keyboard.

GAP CALCULATION

This program performs a calculation to determine the gap needed between two adjacent fields to prevent geometric overlap at depth. The program uses the simple geometric formula:

$$Gap = \frac{1}{2}Length * \frac{Depth}{SSD}$$

Select **G**AP from the Daily Calculations menu. A new screen appears as shown below:

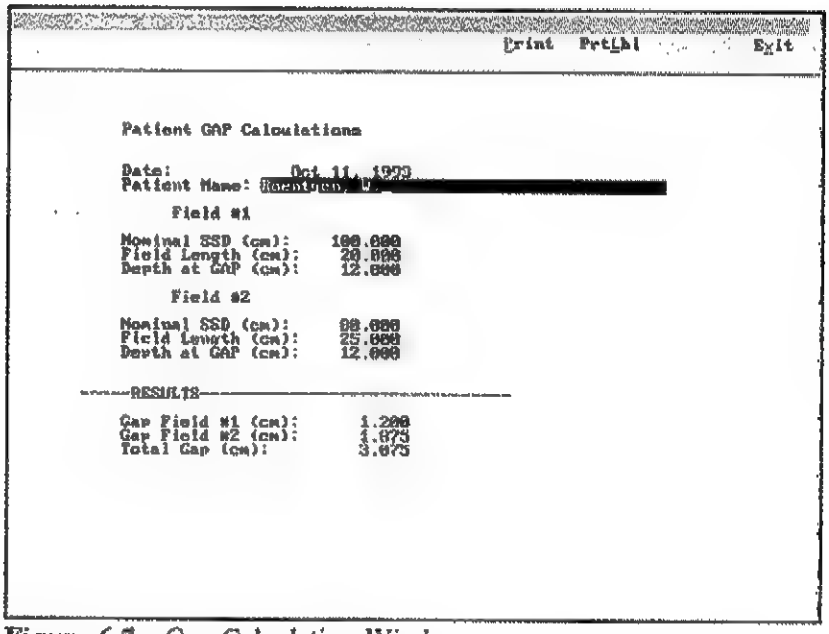


Figure 6.7 - Gap Calculation Window

Enter all of the information requested on the screen. Once enough information has been entered, the results will be displayed at the bottom of the screen. At this time, the Print and PrtLbl menu items appear. Edit any of the items using the arrow keys. The program automatically recalculates the results.

The nominal SSD for the machine is either 80 or 100 cm. The field length is the effective length of the field projected at the nominal SSD. This value must include any blocks at the gap end of the field. The depth required is the depth at the point where the two fields abut. A second depth for non-coplanar beams can be entered. The default for the second depth is that of the first field.

Once the results are satisfactory, print the screen by selecting Print or PrtLbl.

End the program by selecting Quit or ESCape from the keyboard.

IRREGULAR FIELD CALCULATION

CALCULATION DESCRIPTION

The irregular field calculation determines the dose to a set of calculation points from an arbitrarily shaped beam which irradiates a homogenous patient using a modified version of the Clarkson integration technique.

In calculating the TMR seen at each calculation point, an adjusted zero area TMR is added to an average SMR as seen at that point. The zero area TMR at the depth of the calculation point is modified by an energy and profile correction. It is then modified by a block edge profile factor which depends on its proximity to the nearest field-defining block edge.

To determine the average SMR, the beam outline is approximated by 360 pie slice shaped regions each of which encompasses a 5° arc. The SMR associated with each radius is determined and then averaged. For details of this calculation, see the Algorithms section of this manual.

CALCULATION COMPONENTS

To view the irregular field plan of an existing patient, choose **Irregular Field Calculation** from the main treatment planning menu. The irregular field planning window appears as shown in Figure 7.1

The status bar and button bar are seen as in all Prowess products. The components of the irregular field plan are the demographics, beam outline, calculation points, beam parameters, an optional opposed field, and the calculation results.

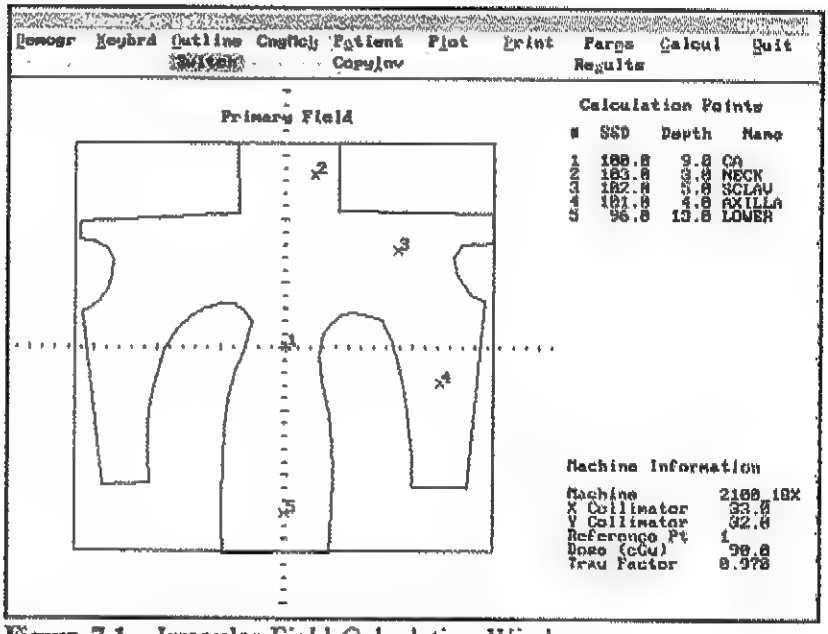


Figure 7.1 - Irregular Field Calculation Window

Demographics

Selecting the **D**emogr option allows entry of the patient's demographic data as shown in Figure 7.2

This data is entered through the keyboard. Select **A**ccept to save the entries or **C**ancel to discard them. The patient's name appears in the status bar of Figure 7.1 and Figure 7.2.

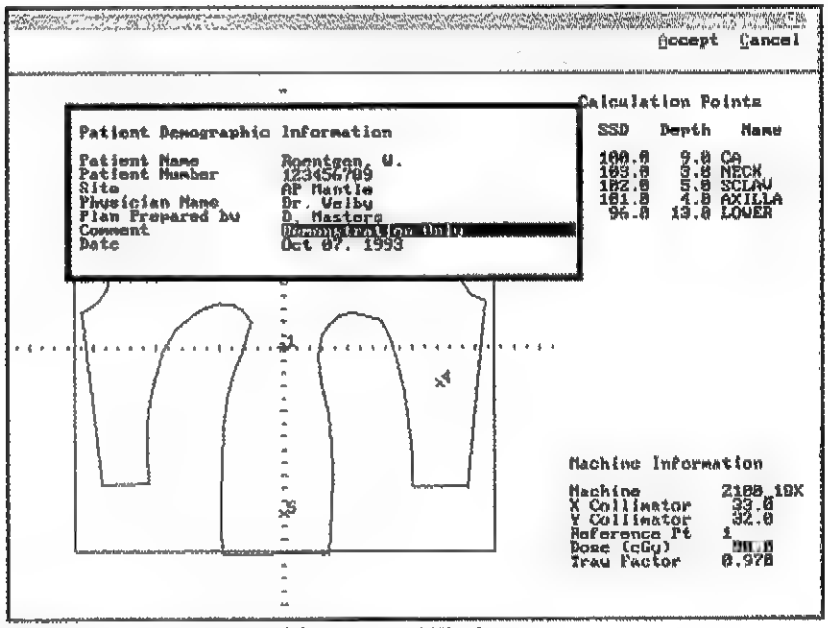


Figure 7.2 - Demographics Entry Window

Beam Outline

The beam outline appears in the center left of Figure 7.1. The blue rectangle indicates the collimator settings. A green set of coordinate axes indicate the beam's central axis and orientation. Color differences around the beam outline indicate differences in blocking type.

To replace the existing beam outline, select Outline. All outline entry is done through the digitizer as shown in Figure 7.3

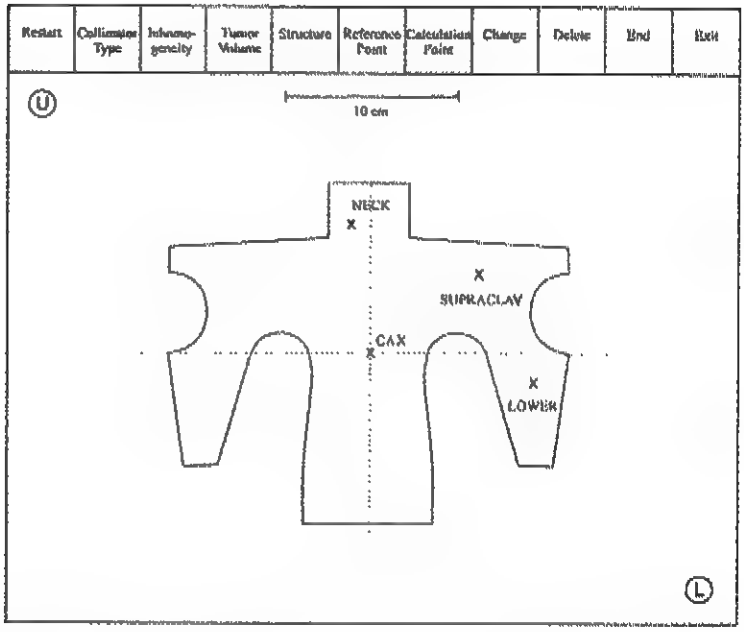


Figure 7.3 - Digitizer Entry of Irregular Field

After selecting this option, you are prompted to digitize the calibration points "U" and "L" and then to either enter the outline scale or digitize both ends of a reference mark. After this, digitize the central axis location and the location of some point along the positive X axis.

Begin digitizing the beam outline in either the clockwise or counter-clockwise direction. Only a single connected field region can be entered. To close the beam outline, select **End**. Then, you will be prompted to enter calculation points. Up to 20 may be selected. Select **Exit** to terminate entry.

Note that the scale of the beam outline must be projected to the plane of the machine isocenter. During outline entry, select **Delete** to delete outline or calculation points.

Calculation Points

The calculation points are shown in the center left of Figure 7.1 overlaid on the beam outline. Each calculation point has a name, depth, and SSD which are user entered. The depth is the depth of the calculation point below the patient surface and the SSD is defined to be the central axis SSD plus the vertical gap between

the central axis SSD point and the projection of the calculation point to the surface. The gap can be positive or negative.

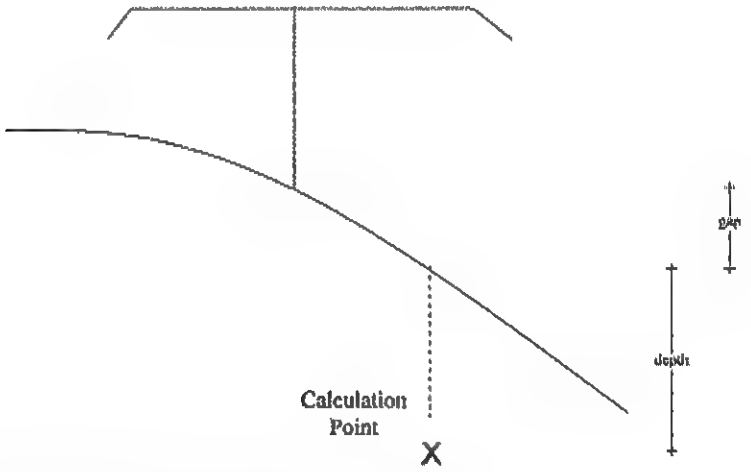


Figure 7.4 - Calculation Point Geometry

To edit the calculation points, select Keybrd from Figure 7.1. A point list is presented as shown in Figure 7.5.

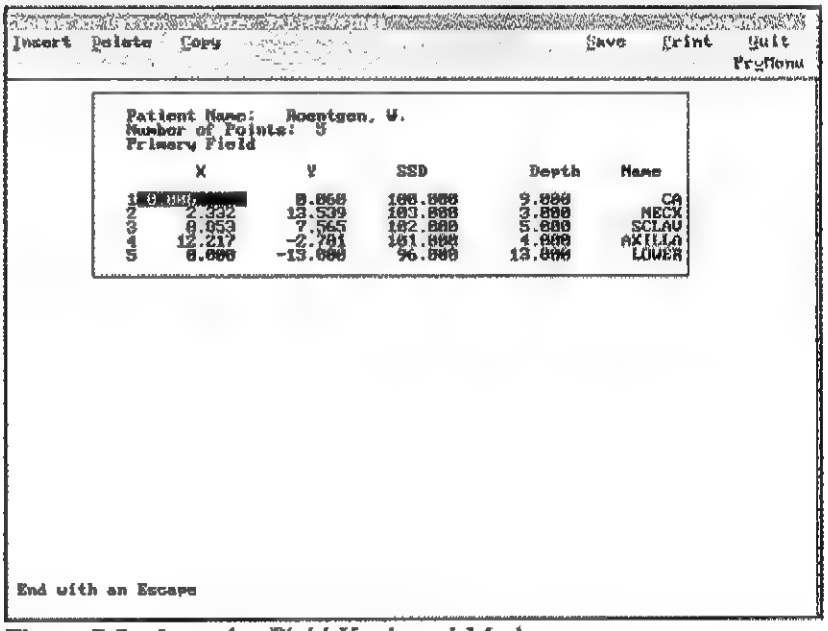


Figure 7.5 - Irregular Field Keyboard Mode

Use the arrow keys to move to any entry in this table. All entries including X and Y location can be edited with the keyboard. All positions are referred to the plane of the machine isocenter. Select Insert or Delete to create new or remove existing calculation points. Choose copy to make a copy of an existing point. Select Print to make a hardcopy print of the list. Select PryMenu to exit point editing without saving or Save then PryMenu to save and exit.

Beam Parameters

The beam parameters are shown in the lower right corner of Figure 7.1. These parameters include treatment machine name, X and Y collimator settings, prescription reference point number, prescribed dose, and tray factor. To edit these values, select Parms. The values are presented as shown in Figure 7.6 and can be edited by keyboard.

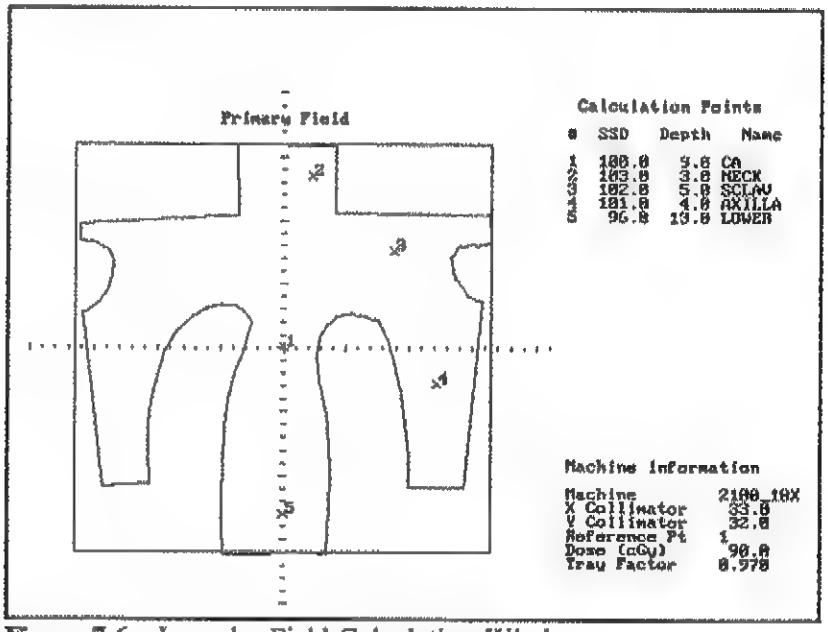


Figure 7.6 - Irregular Field Calculation Window

Opposed Field

A specific treatment calculation may or may not include an opposed field. If there is an opposed field, select CopyInv and the Switch option becomes active. The Switch option can be used to toggle between the primary and opposed fields.

Note that the beam parameters and calculation points are tied to the primary and opposed fields. However, the beam outline is not.

Thus, it is possible to Switch to the opposed field, modify the calculation points, and reweight the beam; but you could not enter a different beam outline.

Calculation Results

Calculation results are obtained by choosing Calcul from the window of Figure 7.1. Calculation results consist of a dose delivered at each point from each beam, machine settings required to deliver the prescribed dose to the reference point, the physical parameters leading to the doses and machine settings, and a blocked effective field size seen by each calculation point. After selecting Calcul, summarized results are shown on the screen. Any calculation points under or near to a block edge are shown in red and should not be used for weighting. To see the complete results select Print and Plot to print hardcopy calculation results and plot the beam outline.

CALCULATION PROCESS

The preceding discussion describes how to edit an existing patient. If, after entering the irregular field calculation you enter a new patient name, a new patient will be created. You will be prompted automatically for the demographics. Select Outline and enter the outline, calculation points, and parameters as described above. When this is done, you can make and edit an opposed beam if needed and Print and Plot the results.

SAMPLE CALCULATION

This section describes calculation of an irregular field using the irregular field program. The field is a mantle used to treat Hodgkin's Disease. Use the field shape enclosed at the end of this section as the beam outline for a sample case.

- Place the contour under the plastic film on the digitizer.

- Measure or enter the magnification of the field from the scale markings.

- Mark the points of calculation on the film and record the SSD and depth of calculation for each point.

- Mark the type of beam blocking at each edge of the field.

- Start the program by selecting Irregular Field Calculation from the main treatment planning menu.

- Enter the patient file name and the demographics.

Patient Name:	Grady, Donald
Patient Number:	12345
Site:	Anterior Mantle
Physician's Name:	CJ
Plan prepared by:	Your Name
Comment:	Any comment

- Press Outlin.

- Select a machine from the list of those available.

- Enter the magnification.

- Proceed through the calibration by touching points "U" and "L" with the stylus on the digitizer.

- Digitize the origin at the central axis of the beam and a point on the major axis to the right of the origin on the axis of the beam.

- The default value for the edge type is set to collimator. Touch the digitizer box labeled **Collimator Type** to change the collimator type. Select the type of beam edge from the screen.

- Enter the shape of the field point by point. You may enter it in either direction.

- Touch digitizer box labeled **End** when you are finished.

- Now enter the calculation points. Once these are completed, touch digitizer box labeled **End.**

- You have now completed digitizer entry for this program. Touch digitizer box labeled **Exit**

- Enter the SSD, depth, and description of each calculation point.

Point 1 SSD	: 100.0 cm	
	Depth	: 10.0 cm
	Description	: CA

Point 2 SSD	: 105.0 cm	
	Depth	: 5.0 cm
	Description	: Neck
Point 3 SSD	: 101.0 cm	
	Depth	: 9.0 cm
	Description	: Axilla
Point 4 SSD	: 94.0 cm	
	Depth	: 14.0 cm
	Description	: Lower

- Edit field parameters.

X Collimator size:	28.000 cm
Y Collimator size:	30.000 cm
Calculation Point:	1
Dose (cGy):	90.000
Tray Factor:	0.970

- Press Calcul to calculate the irregular field. The calculation summary for each point will appear at the bottom of the screen. Press any key to continue.

- Select Print to print.

- Select Plot to plot the results. Enter "Anterior Mantle" as title, scale factor of 0.5, and Y to 8½"x11" paper size.

- Select Quit to exit the Irregular Field program and return to the main treatment planning menu.

The results of this calculation are shown in the following figures.

BRACHYTHERAPY CALCULATIONS

PROGRAM DESCRIPTION

The Brachytherapy program calculates the dose distribution for radioactive line sources or seed implants. Point, planar, and volume calculations can be made.

Source locations are input to the brachytherapy program using:
- Orthogonal films on the digitizer.
- A template.
- The keyboard.
- Stereo films using a fiducial jig.
- Axial ultrasound contours.

A maximum of 500 line sources or 1000 seed sources may be entered. The sources may be mixed in any combination of activity and type.

The location of sources and points of interest are displayed on the screen. You may change the source activity or isotope without affecting source location or other parameters.

The dose distribution can be calculated in any plane. The calculation plane may be translated or rotated about any of the three coordinate axes. The orientation of each plane's rotation and translation is maintained on the screen at all times. The two planes perpendicular to the calculation plane are displayed on the screen continuously. A line through these planes show the depth of the calculation plane. You may change the calculation window size and the magnification. The calculation size limits are 100 to 4096 matrix points; the default is 1024.

Patient data files can be saved and retrieved. Each data file and hardcopy output is uniquely identified and correlated by assigning a plan date and time to each patient implant calculation.

A summary sheet for each plane of calculation can be printed showing demographic data, source data, calculation time, and dose for specific points from each source. The isodose distribution may

be plotted to provide a hardcopy record. The hardcopy records should be placed in the patient file to provide a permanent record of the treatment.

To recheck the Brachytherapy Calculation program from the main planning menu, select **Brachytherapy Calculation.**

The program asks for a patient file name which may be any combination of characters except blanks. The file name should contain at least three, but no more than eight characters. If the file name is unique, a new patient file is created. If the file already exists, it is retrieved for planning. Should you want to retrieve an existing patient file, press the down arrow key or point the mouse to the square marked **List Patients** and click. A list of all of the patient files on the hard disk will appear in a window which contains 10 patient file names in alphabetical order. Use the arrow keys or mouse to select one of these patients. If the patient is not shown in the window use the arrow key or the mouse to locate the desired name. Once you have selected the patient desired press **Enter.**

The main brachytherapy planing window is shown in Figure 8.1.

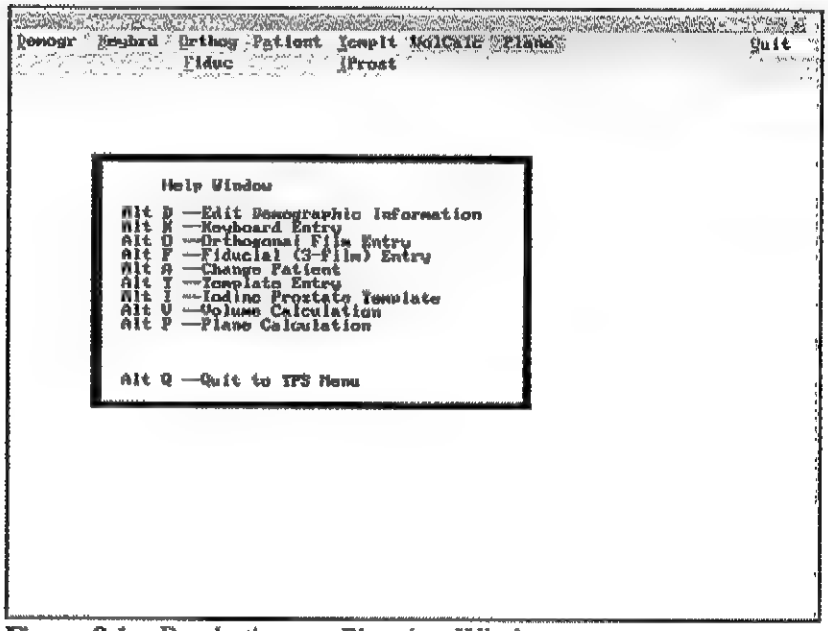


Figure 8.1 - Brachytherapy Planning Window

Demogr - editing/entry of patient demographic data
Keybrd - editing/entry of sources from the keyboard
Orthog - orthogonal source entry using the digitizer
Fiduc - entry of source coordinates from a fiducial (stereo) jig
Patient - allows you to retrieve a new patient file
Templt - provides entry of source coordinates from a template
Iprost - provides entry of multiple planes for permanent seed prostate implant design
Volcalc - performs a volume calculation and displays a graph of the dose or dose rate volume
Plane - displays the plane of calculation
Quit - allows you to exit the program
ESCape - causes the program to EXIT

PATIENT DEMOGRAPHIC DATA

Patient demographic data may be updated at any time during the planning process by selecting **D**emogr from the main brachytherapy planning menu. When a new patient is first entered, you must fill out the demographic data before proceeding with the source entry and further planning. This is done by entering the names of the patient, doctor, planner, treatment site, comments, and date. You may use the arrow keys to move up and down the screen to edit any entry. Selecting **A**ccept saves this information.

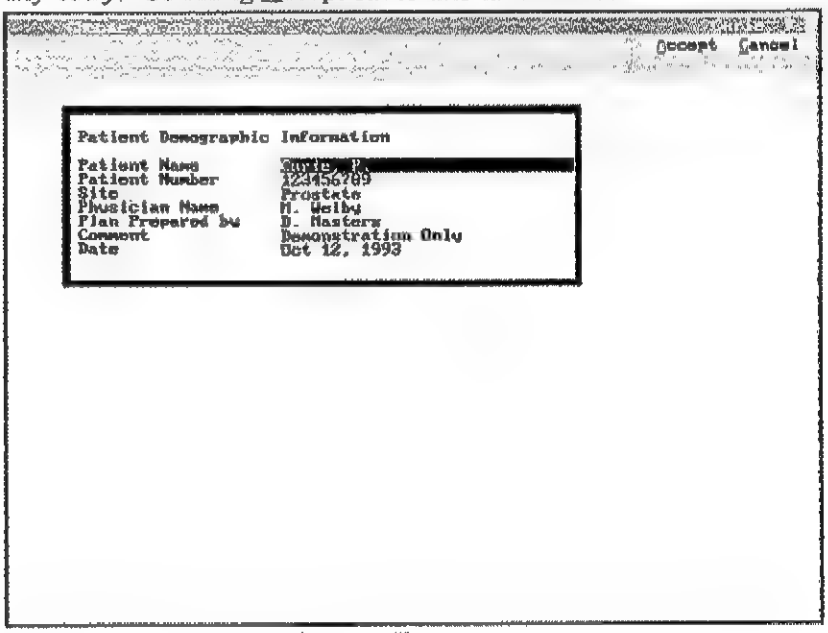


Figure 8.2 - Demographic Data Entry

ORTHOGONAL FILM ENTRY

Before entering the source coordinates from a pair of orthogonal films, the films must be prepared. Orient the two films so that their common axis is vertical (y-axis). Choose one film to enter first (usually the AP film). The horizontal axis is the x-axis.

The sources on the two films must be matched. For seed sources, each source location must be labeled and matched on both films. For line sources, each end must be aligned. If the strength of each source is different, then the activity should be included on the film. Line sources are assumed to be uniformly loaded.

Place the two films side-by-side on the digitizer table. Choose Orthog from the main brachytherapy menu to start entry.

Warning: *Do not* mix radiation sources permanently implanted in the patient with temporary sources without carefully considering the results. PROWESS recommends not using the brachytherapy calculation program to mix permanent and temporary seed sources. Interpretation of the dosimetric results may be difficult.

You are first prompted to enter the source type for the first source. The screen displays your choices. You must select one of these source types. The source strength is entered next. The source strength is typically specified in milligram Radium equivalent (mg Ra eq) or millicuries (mCi).

Next, you are prompted to "Enter the magnification from the digitizer, Y or N ?" An answer of **N** will allow you to type in the magnification of each film to be entered. An oversized film will have a magnification greater than 1.000. The default magnification is 1.000. The magnification may be entered from the digitizer. If the magnification is to be entered from the digitizer, it is necessary to enter the length of the marker in centimeters.

Next you are prompted to digitize points **U** and **L** which are in the upper left hand and lower right hand corner of the digitizing area.

Note: To make the digitizing stylus work correctly, slight pressure must be put on the point to activate the switch within the stylus. Always hold the stylus at the same angle, preferably perpendicular to the surface.

The digitizer has an approximate calibration that returns numbers to the computer to the nearest 0.01 cm. The program checks the data

received from digitizing points **U** and **L**. If the digitizing factor is within ±.5%, then this is considered satisfactory. If an error was made in this calibration, such as allowing the stylus to digitize at incorrect positions, the computer will signal an error has occurred and instruct you to reenter points **U** and **L**.

If you previously indicated that you were entering the magnification from the digitizer, you will now be asked to digitize two points that correspond to the dimension already given.

The films should have been put on the digitizer side-by-side. Remember, the common axis of the two films is vertical. From this point you will be prompted to digitize the origin for film one. After digitizing the origin you are asked to enter a point to the right of the origin parallel to the axis. This point is used to align the axis of the film to the digitizer.

A split screen appears once the preliminary information is entered. Coordinates for film one will appear on the left, and film two on the right. Sources are digitized one source at a time and the location of the sources are shown on the screen. If you elect to change the source type or strength during entry of film one, touch digitizer box labeled **Change**. At this point you are asked to reenter the source type and strength on the keyboard for the remaining sources. Continue to enter the sources. Each time a source is to be changed, touch digitizer box labeled **Change** and the appropriate questions are answered.

To enter points of calculation, touch digitizer box labeled **Calculation Pts** before ending the film entry. Up to 20 points may be entered. These points should be entered after the source coordinates and must be entered before starting the next film.

Once all of the coordinates for film one are entered, touch digitizer box **End** to complete this film and start film two. Enter the coordinates for film two.

When all of the sources have been entered, the program makes a 'least squares fit' of the coordinates in the axis which is common to both films defined as the Y axis. If the two sets of Y data are plotted on linear graph paper you would see a line at 45 degrees through the origin. A line which does not pass through the origin is an indication of an unsatisfactory origin. The origin error must

be removed before any subsequent change in magnification. Changes in magnification will not effect errors differentially for points further away from the origin.

When the line is not at 45 degrees, this indicates that one or both films have the magnification factors entered incorrectly. The ratio of these errors is shown at the bottom of the screen. A perfect fit between the two films would differ by 1.000 with a variance of 0.000. If the magnification differs by <5%; that is, the ratio is between 0.95 and 1.05, then you may wish to proceed without further change. A variance >.05 is indicative of bad data entry. If this occurs, you should consider reentering all sources. Once you are satisfied with the source coordinate entry, you may accept this data. At this point you are prompted with "Save this data, Y or N?". If you type Y the coordinates are saved on the hard disk for calculation.

STEREO FILM ENTRY

The use of stereographic radiographs described in this section are based on manual methods of three-dimensional reconstruction which have been used for many years (Nuttall and Spiers, 1946; Mussel, 1956; Shalek and Stoval, 1962).

Radiographic Technique

PROWESS requires the use of a special apparatus called a fiducial jig during stereoradiography as described in Appendix B. This fiducial jig contains lead markers called "fiducial points," which are embedded in two parallel plastic plates, one beneath the patient and the other over the patient. See Figures 8.3 and 8.4.

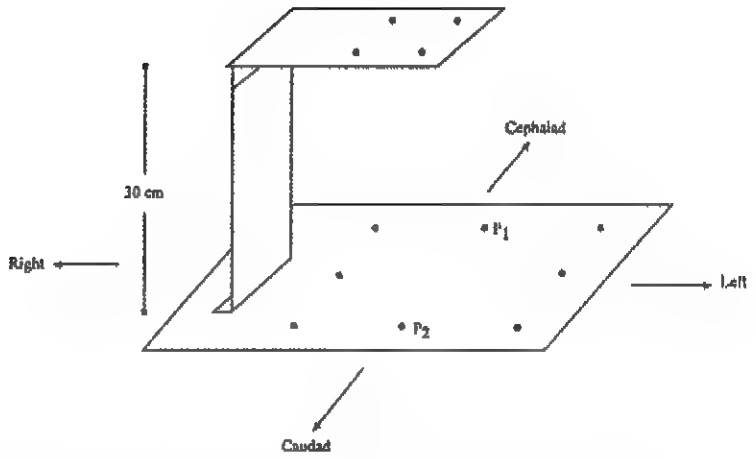


Figure 8.3 - Perspective View of Fiducial Jig (not to scale)

The usual technique is as follows:

1) Use 14"x17" films.
2) Place the patient on the table with the jig positioned as in Figure 8.3. The arm of the jig should be on the patient's right side. A magnification ring is not necessary.
3) Use a target-film distance of 100 cm.
4) Take the first exposure with the central ray passing through point P_1, shown in Figure 8.3. Radiography with 80-90 kV should have good contrast.
5) Shift 20 cm along the long axis of the patient and take the second exposure with the central ray passing through point P_2, shown in Figure 8.3.

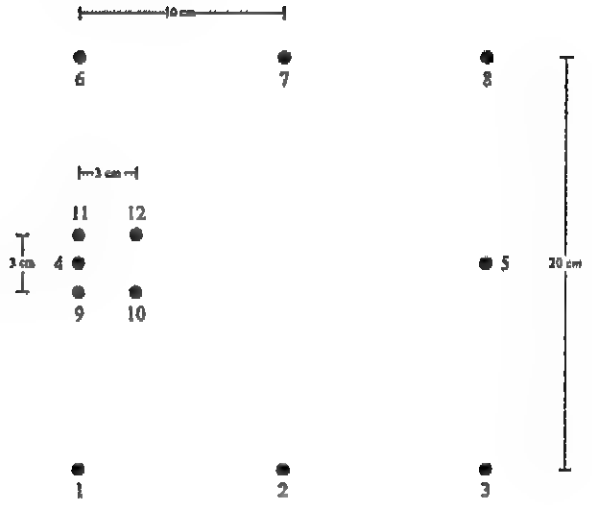


Figure 8.4 - Vertical View of Fiducial Points

Do not allow the patient to move between exposures. Also, be sure the patient does not lean against the arm of the jig and alter the geometry of the lead shot.

Since fiducial points are used, the geometric relationship of the x-ray target and the films are not critical. From the data given, the computer calculates the actual target-film distance and the shift distance used. Record the distance between the lower plate and the cassette (typically 5-12 cm).

The fiducial point positions are stored in a file called SFPID.TXT in the MACHINE directory. Using this data, as well as the location of the images of lead shot and sources on the films, the computer calculates the location of the sources.

Before entering the source coordinates from a pair of films, orient the two films so that the common axis is vertical. Choose one film to enter first.

The sources on the two films must be matched; i.e., each seed source and calculation point must be labeled and matched on both

films. The ends of each line source must be matched. If the source strength of each source is different then the activity should be included on the film. Line sources are assumed to be uniformly loaded. Mark the fiducial marker points as shown in Figure 8.4. The points must be entered in order.

Entering the source coordinates with the digitizer is started by selecting **E**iduc from the main brachytherapy planning window. Then, you are prompted to enter a source type for the first source. If you forget the selection of source codes, the screen displays your choices. You must select one of these source types. The source strength is entered next.

Next you are prompted to digitize points **U** and **L** which are in the upper left and lower right corner of the digitizing area.

The films should have been put on the digitizer side-by-side with the common axis of the two films vertical. From this point you will be prompted to digitize the origin for film one (use fiducial point 1). After digitizing the origin you are asked to enter a point to the right of the origin parallel to the axis (use fiducial point 3). This point is used to align the axis of the film to the digitizer.

A split screen appears once the preliminary information is entered. Coordinates for film one will appear on the left and film two on the right. Digitize the 12 fiducial points first then the sources. Sources are digitized one source at a time and the location of the sources are shown on the screen. If you elect to change the source type or strength during entry of film one, touch the digitizer box labeled **Change**. At this point you are asked to reenter the source type and strength on the keyboard for the remaining sources. Continue to enter the sources. Each time a source is to be changed, touch digitizer box labeled **Change** and the appropriate questions are answered.

To enter points of calculation, touch digitizer box labeled **Calculation Pts** before ending the film entry. Up to 20 points may be entered. These points should be entered after the source coordinates and must be entered before starting the next film.

Once all of the coordinates for film one are entered, touch digitizer box **End** to complete this film and start film two. Next enter the fiducial and source coordinates for film two.

When all of the sources have been entered, the program displays the location of the x-ray source and the errors in the entry of the source coordinates. A variance of >.05 is indicative of bad data entry. If this occurs you should consider reentering all sources. Once you are satisfied with the source coordinate entry you may accept this data. At this point you are prompted with "Save this data, Y or N?". If you type Y, the coordinates are saved on the hard disk for calculation.

TEMPLATE ENTRY

A popular technique for implanting radioactive material is to use a predefined template to geometrically arrange and hold the sources in place. Since the geometric pattern of holes is well defined in one plane, only the source location or ribbon loading in the other direction need be specified.

To expedite data entry, an ideal template input option has been developed to allow rapid and accurate specification of an ideal template implant. Before using this option the geometric location of the needle pattern must be entered using the template program described in another section.

In practice, most of the implants do not adhere to the ideal geometry. The needles usually follow a uniform geometric path but tend to splay (spread) or cone (converge) at the tips. The template entry program allows correction for coning at the upper and lower ends of the implanted needles and in the two directions in the plane of the template.

A coning of 1.0 means no change from the ideal. The coning factor is the ratio of the actual template diameter/physical template diameter, the coning correction modifies all template tubes evenly in the specified direction and end. No correction is made for non-uniform source positioning. A value of <1.0 means convergence and a value of >1.0 means divergence. An example: Should the outside dimension of the template measure 5.0 in one direction and the end of the needles measure 4.5, then the coning is 0.9. The coning correction treats all of the sources uniformly. Should one or two source strings be askew, they will require hand entry or correction using the keyboard. See Figure 8.5.

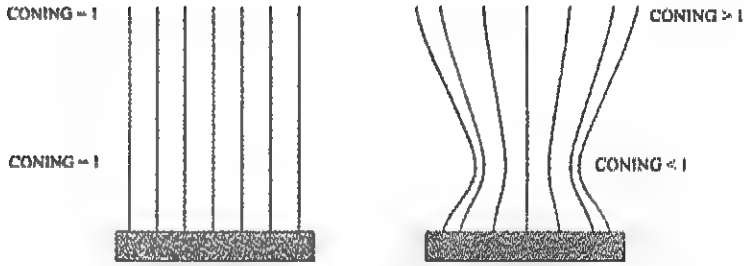


Figure 8.5 - Template Implant Coning

Entering the source coordinates using predefined templates is started by selecting Templt from the main brachytherapy planning window. Select one of the templates listed. The screen then displays the template with questions to be answered below. For each ribbon location, enter the source code type, activity, number of sources per ribbon, spacing between sources, and the offset for the first source in the ribbon. If the source code is not a valid number then a pop-up window will display the choices.

Using the arrow keys allows editing of all entries of all sources. As the questions are finished for each source, the template color changes. Green represents template points not described; red: points already described; and yellow: the active template location.

Following entry of all template locations, the coning can be applied by answering the question "Is there coning - Y or N?" with a Y. Then enter the coning factor for both ends of the loaded template in the horizontal and vertical direction. Following entry of the coning factor, the coordinate can be printed or accepted. To print the template loading, choose Print. Accepting the template coordinate is done by selecting Accept. This saves the template pattern just entered. To load the source coordinate and save, answer Y to the question: "Save coordinate, Y or N?"

IODINE PROSTATE SEED ENTRY

To design the source loading for an implant from serial transverse contours, such as ultrasound scans from a rectal probe, select IProst. Line up all of the equally spaced scans on the digitizer in order of depth. Be sure the two points called **A1** and **G1** (6 cm to the right of A1) are marked on each scan. These points will be used to align and scale each scan.

Enter the points **U** and **L** which are in the upper left and lower right corners of the digitizer area. Start with the first contour and digitize points **A1** and **G1**. Next, trace the contour of the area to be implanted. Close the contour by touching the digitizer box labeled **End**. Enter contour 2 through N as you did the first contour. When you have finished with the last contour, end by touching digitizer box labeled **Exit**.

Enter the source type of all the sources and their strength. The source strength of ^{125}Iodine or other permanent implant isotope is specified in millicuries or millicurie-hours depending on the desired dose distribution to be calculated. ^{125}I activity in mCi produces a dose distribution in cGy/hour. Activity specified in millicurie-hours produces a dose distribution in total cGy. Next, enter the spacing between scan cuts in centimeters.

The program will load the template by choosing one of the load options with sources spaced at 1.0 cm apart on planes spaced 1 cm apart. If the scans are 0.5 cm apart then every other plane will show no sources. LdNoSft load the sources in the holes with capital letters, while LdSht loads source in holes with small letters. Unload removes all sources. Sources can be edited using the function keys as shown:

Increment	Decremt	Insert	Delete	SrcChng LdSft	LdNoSft	Load/Sv Unload	Print	Quit

Move the cursor with the arrow keys. Each step is 0.5 cm. Increment increments the scan planes and Decremt decrements the scan planes. Insert adds a source to the plane and Delete deletes a source. The mouse can be used to Load and Unload sources. Move the mouse to the point to be changed and click once. The active box moves to that location checked again and the loading reverses. Click again and it reverses again. Using the mouse this way, all template locations can be edited. Print prints a summary of the template loading as shown on the following page. Load/Sv transfers the template design to the calculation coordinates and saves the template loading. Quit exits the entry. To save the loaded source coordinate answer Y to the question "Save coordinate, Y or N?"

To calculate this plane from the main planning menu, select Plane and the sources will be displayed on the screen. Select Batch and the screen will show a cross section of all the plans scanned

overlaid on the sources entered. Press any key to calculate the planes. Upon completion of the calculation, batch plotting can be done or one plane at a time can be shown on the screen. Choose one of the planes by using the arrow keys to pick a plane. After selecting a plane, the treatment contour is shown on the source coordinate. Choose the appropriate isodose lines to describe the dose distribution. End the isodose selection with an ESCape. At this time the following menu appears:

Isodose	Time	Rings NumOff	Slides	Print	Plot	PlotAll	Quit Help2

PlotAll allows batch plotting of all the planes. Plot plots the plane displayed, Print prints the normal source description. The only way to exit the batch mode is by selecting Quit.

If you want to edit the template design, go back to the main brachytherapy planning menu and reselect Iprost. Choosing the Old plan will return you to the previous template loading.

KEYBOARD ENTRY AND EDIT

Having selected Keybrd, the computer displays the coordinate source type and strength of all the sources. If this is a new file, select Insert for the number of new sources to be added. Then enter the source locations, source types, and source strengths in the appropriate position. Remember, all of the data on the screen may be edited. If it is satisfactory, select Accept to accept the new entries.

PLANAR CALCULATIONS

From the main brachytherapy menu screen a plane is selected by choosing Plane. If an old plane exists you may choose one of these. Otherwise, a new plane approximating the first film is shown on the screen with the following set of function key labels:

XCW1 Isodose	XCCW2 InitSet	YCW3 Time	YCCW4 NumOff	ZCW5 ShoPts	ZCCW6 Print	Swap A Plot	Swap B Batch	Calcul Misc	Quit Help2

The projection of the sources in the calculation plane immediately comes to the screen in the large window. Two perpendicular views are shown to the right labeled View A and View B. The axis of each window is labeled appropriately.

If this is a new plane, then the plane digitized first will be shown on the screen. This may be the anterior view. The calculation plane may be rotated using the functions. For example, selecting XCW1 once, rotates the implant about the viewed X-axis by 10 degrees and thus brings the anterior axis upward on the screen by a small amount. Note that the projection in all three windows change as the plane is rotated. A vertical line through the implant shows the depth of calculation of the plane. If at anytime you are lost, you can get back to the original orientation by selecting InitSet.

Williams, Ralph

.y 23, 1993 - 13:26:43 Physician: REA
Site: Prostate
ID Number: 2315
Plan prepared by: PHH

Template Printout

Sources Description: 0.481 mCi I-125, Type 103
Calculated Activity: 1000.000 mCi-hr

	A	a	B	b	C	c	D	d	E	e	F	f	G
6.0	.	.	.	.	.	.	.	.	.	.	.	.	.
5.5	.	.	.	.	.	.	.	.	.	.	.	.	.
5.0	.	.	.	.	.	.	.	.	.	.	.	.	.
4.5	.	.	.	.	.	.	.	.	.	.	.	.	.
4.0	.	.	.	.	.	1	.	2	.	3	.	.	.
3.5	.	.	.	.	.	.	.	.	.	.	.	.	.
3.0	.	.	.	.	.	4	.	5	.	6	.	.	.
2.5	.	.	.	7	.	.	.	.	.	.	8	.	.
2.0	.	.	.	9	.	10	.	11	.	12	.	.	.
1.5	.	.	.	.	13	.	.	.	.	14	.	.	.
1.0	.	.	.	.	15	16	17	18	19	.	20	.	.

Total Number of seeds = 29

Summary of Needle Loadings

Needle	Retraction (cm)	Hole Location	Number Seeds
1	1.0	c4.0	1
2	1.0	d4.0	1
3	1.0	e4.0	1
4	1.0	c3.0	2
5	1.0	d3.0	2
6	1.0	e3.0	1
7	1.0	b2.5	1
8	1.0	F2.5	1
9	2.0	b2.0	1
10	0.0	c2.0	3
11	0.0	d2.0	3
12	1.0	e2.0	2
13	0.0	C1.5	1
14	0.0	e1.5	1
15	1.0	C1.0	1
16	0.0	c1.0	2
17	1.0	D1.0	1
18	0.0	d1.0	2
19	1.0	E1.0	1

Needles Needed

Number Needles	Seeds/ Needle
13	1
5	2
2	3

Summary of Needle Loadings (continued)

Needle	Retraction (cm)	Hole Location	Number Seeds
20	1.0	F1.0	1

an Checked by _____ Plan Approved by _____

The X, Y, and Z angles of rotation and plane depth are continuously displayed on the lower left of the screen. These quantities are updated as the plane is rotated and translated to achieve the desired cut. If you find that there are too many source numbers on the screen, you may turn off the source numbers by selecting NumOff.

In order to tell which sources are above or below the plane, three colors have been used to designate the sources or part of the source in the plane. If the source is above the plane, it is shown in green as a large box. If the source is within ±0.5 cm of the calculation plane, it is shown in white as a small box. A source below the calculation plane is shown in red in a tiny box. If the sources are line sources, then the intersection of the plane of calculation with the source is indicated by the change of color from red to green. As the plane is rotated or translated, the user will notice that these colors change to designate which sources are in, above, or below a calculation plane.

The size of the calculation window is the size of the plane of calculation. A centimeter rule through the plane indicates absolute size. If you do not want to see the dose to the tissue surrounding the implant and wish to have greater detail towards the center, then the scale may be changed by selecting Misc and change the window size. The matrix size can also be changed with this Misc function. The matrix size may be varied from 100 points to 4096 calculation points. The angle and position increment may also be varied from within this window.

Rotate and Translate Source Coordinates

Six function keys are used to rotate and translate the calculation plane to achieve the desired cut. Each time a function is activated by letter or clicked on with the mouse, the screen is updated and the display changed to show the appropriate rotation or translation. The following keys are used to rotate or translate the calculation plane:

XCW1	XCCW2 InitSet	YCW3	YCCW4 NumOff	ZCW5	ZCCW6	Swap A	Swap B Batch	Calcul Misc	Quit Help?

Each function displayed is listed below:

XCW1 - rotates the calculation plane one angle increment in the positive X direction.
XCCW2 - rotates the calculation plane one angle increment in the negative X direction.
YCW3 - rotates the calculation plane one angle increment in the positive Y direction.
YCCW4 - rotates the calculation plane one angle increment in the negative Y direction.
ZCW5 - rotates the calculation plane one angle increment in the positive Z direction.
ZCCW6 - rotates the calculation plane one angle increment in the negative Z direction.
Up Arrow - moves the plane offset in the positive direction perpendicular to the calculation window one depth increment.
Down Arrow - moves the plane offset in the negative direction perpendicular to the calculation window one depth increment.
InitSet - returns the plane angles and depth to their initial value of 0.0.
NumOff - erases the source numbering and point numbering from the display. This is a toggle and will also turn the numbers on.
Swap A - allows you to swap the calculation plane window for View A.
Swap B - is the function which allows you to swap the calculation plane window for View B.
Plot - will give you the isodose curves in hardcopy.
Print - provides a hard copy of the source descriptions, activities and a listing of the dose to the calculation points.
Batch - allows you to enter the batch calculate and plot mode.
Misc - gives you the opportunity to change the limits of calculation, move the calculation window, change the angle and position increment and change the matrix size.
Help? - displays the summary of the function of all the active functions.

CALCULATION

Calcul starts the calculation of the plane shown to the left. The source number being calculated is displayed at the bottom of the screen as the dose distribution is calculated. The beeper sounds and default isodose values appear after the last source is calculated. Pressing **ENTER** after each value will plot the respective isodose curves on the screen. These values may be edited and new values added. You will note that if you have changed any of the isodose values, in subsequent calculation, your own values are now offered as default values in ascending order. These may be changed as many times as you would like until you feel that you have selected the isodose curves you want. Up to 17 isodose values may be entered on each plane.

ShoPts only operates if you have previously entered some calculation points. It will bring up the dose to the calculation points on the screen.

Paris After calculating a menu item, Paris appears where Calcul was found. It allows you to change the isodose display into a Paris dose display. Choose Paris, then select the basal dose. For that time, the isodose display will be in terms of % basal dose Hardcopy with this option is also in terms of the basal dose.

Time Time allows you to enter the time this implant was left in the patient. Entering the time in hours reports the dose to calculation point in cGy. Default time is one hour.

PLOTTING

Plot selects the plot option. The isodose values selected for screen display will again reappear. You may edit these values for plotting. Press ESCape once you are satisfied with these values. Be sure that the power to the plotter is ON before answering the remaining questions. The screen will display the maximum scale factor allowed by the plotter and ask you for the desired scale factor. A value of 1.0 produces a life-size plot. The program proceeds to ask you whether the paper is 8½"x11" or 11"x17".

Having selected the paper size for the plot the plotter begins operation. Should you wish to stop the plotting before it is complete or an error occurs during the plotting, press ESCape to return to the program.

PRINTING

Print is the function key to select printing. This option provides a printed copy of the sources in this calculation and the dose to the specific calculation points. Patient name, calculation data, and time are duplicated on the printed copy for identification. These should be included in the patient file.

BATCH PROCESSING

Choose batch to process multiple parallel planes. Select the range of planes from bottom to top and the interval in centimeters. Once the calculation is complete the isodose curves are displayed for the

lowest plane. Use the arrow key to step through the planes. A new menu appears:

Isodose	Time	Rings NumOff	Slides	Print	Plot	PlotAll	Quit Help?

Choosing Slides displays all the planes calculated simultaneously. This allows you to examine each plane and compare it easily to the adjacent plane.

Choosing Rings displays the slices in a stacked 3-D projection. The projection may be rotated using the appropriate menu selections. A touch of any rotation key produces the appropriate 45 degree rotation. If the image is cluttered, you may want to select fewer isodose curves and redisplay the ring structure. Choosing print from within Rings produces a plot of the display shown on the screen.

Exit batch processing with the Quit key only.

VOLUME CALCULATIONS

After source entry, a volume analysis can be performed by selecting Volume from the main menu.

When you start the volume calculation, the 4096 volume element matrix is calculated. The actual volume is automatically selected by forming a volume that is 2 cm larger than the maximum coordinate of the sources. All sources are enclosed in the volume by a clinically significant margin. The dose rate (or dose) is calculated to each element.

Once this calculation is complete, a graph appears on the screen showing the dose rate vs.:

a) volume receiving dose rate.
b) volume review dose rate or higher
c) non-uniformity ratio

The non-uniformity dose rate is useful for selecting the tumor dose rate for an interstitial dose rate. The critical dose rate is where the exponential curve shows an inflection.

Alternately, you may perform a contiguous volume analysis. Select Contig to start the analysis. Once the analysis is finished, a plot appears on the screen. The plot shows total volume and

contiguous volume. Below the graph is shown the intersection of the two lines. This point is where the whole volume begins to fragment. These results are shown in a table displayed by choosing Tabls. The table summarizes the contiguous volume, its size, surface area, and location. Print the table by selecting Print. The critical dose rate is chosen from this curve by finding the point where the total volume or contiguous volume curves converge. This is supposed to be the minimum tumor dose rate.

To change the range of dose rates analyzed, select Range and enter your new range of dose rate. This entry affects both the table and the graphics. If no intersection is displayed, it is outside the dose range selected.

BRACHYTHERAPY SOURCE and TEMPLATE EDITING

SOURCE ENTRY

The Brachytherapy Source Edit Program is used for entry and editing of the physical properties of brachytherapy sources. To reach this option from the main menu, select Configuration, then Source Edit Program. The source edit window is shown in Figure 9.1.

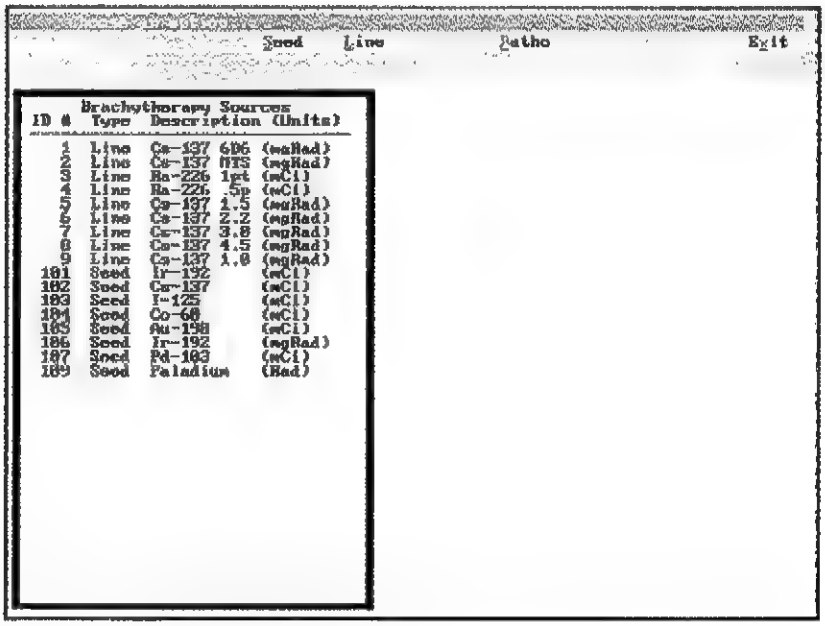


Figure 9.1 - Source Edit Window

From this window, you can select to enter data for a Seed source or a Line source. Also, you can generate a Batho "along and away" table.

Seed Entry

To enter the description of a brachytherapy seed source, select Seed from the source edit window. Specify a source number between 101 and 199. The seed edit window will be presented as shown in Figure 9.2.

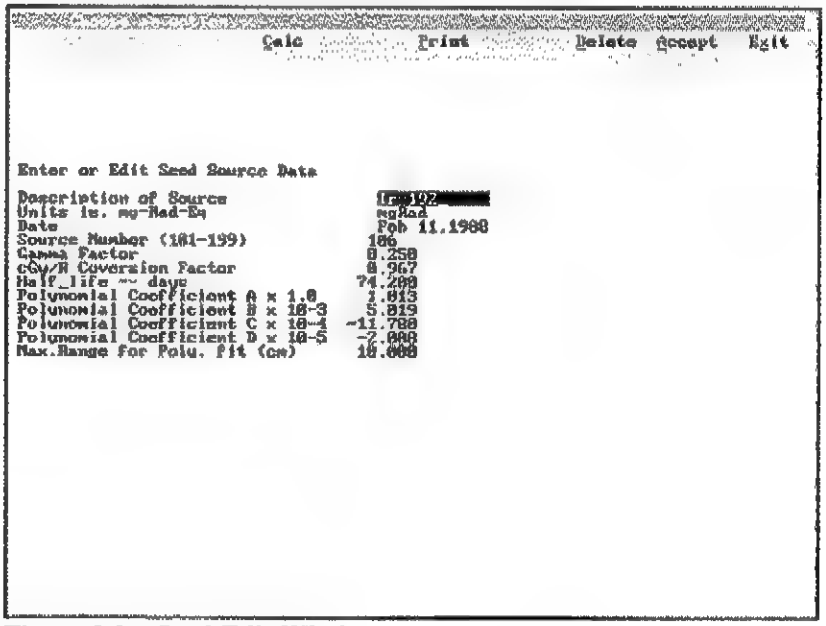


Figure 9.2 - Seed Edit Window

Using the keyboard, enter the source parameters shown in this window. Verify that all source parameters are entered using consistent units. An exponential extrapolations will be used to calculate doses beyond the maximum range for a polynomial fit.

Warning: Verify the entered parameters for each source type before clinical use. Parameters are verified by comparing the dose distribution calculated by Prowess using these parameters with measured or published dose distributions.

Select Print to print out the parameters or Delete to delete the current source. After the parameters are entered, select Calc and Accept or Exit.

Line Entry

To enter the description of a line source, select Line from the source edit window. Specify a source number between 1 and 90. The line edit window will be presented as shown in Figure 9.3.

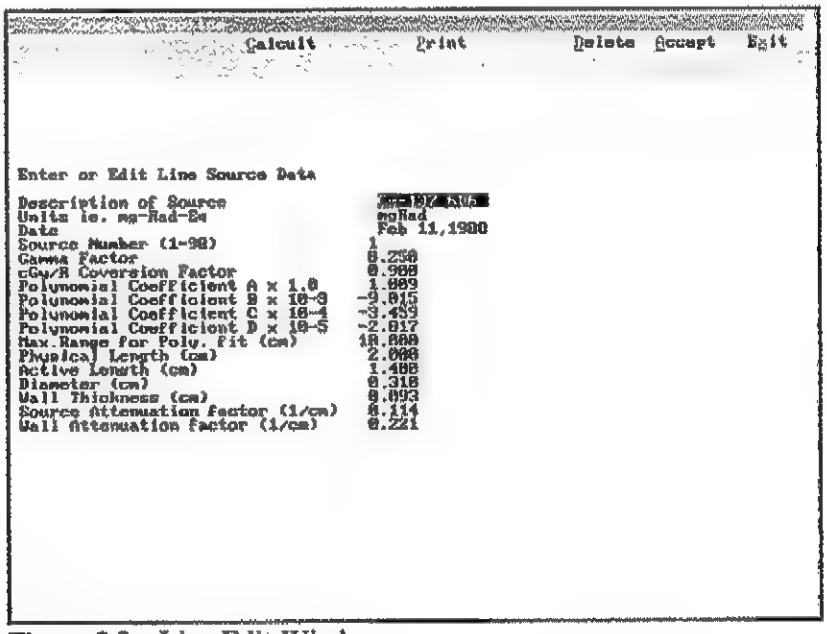


Figure 9.3 - Line Edit Window

Note that all of the seed parameters are required in addition to source geometry and self attenuation properties.

Warning: Verify the entered parameters for each source type before clinical use. Parameters are verified by comparing the dose distribution calculated by Prowess using these parameters with measured or published dose distributions.

Select Print to print out the parameters or Delete to delete the current source. After the parameters are entered, select Calc and Accept or Exit.

Table Calculation

After entry of a seed or line source, a Batho "along and away" table can be calculated by selecting Batho from the source edit window. As shown in Figure 9.4, this data can be printed by selecting Print. Chose Exit when done.

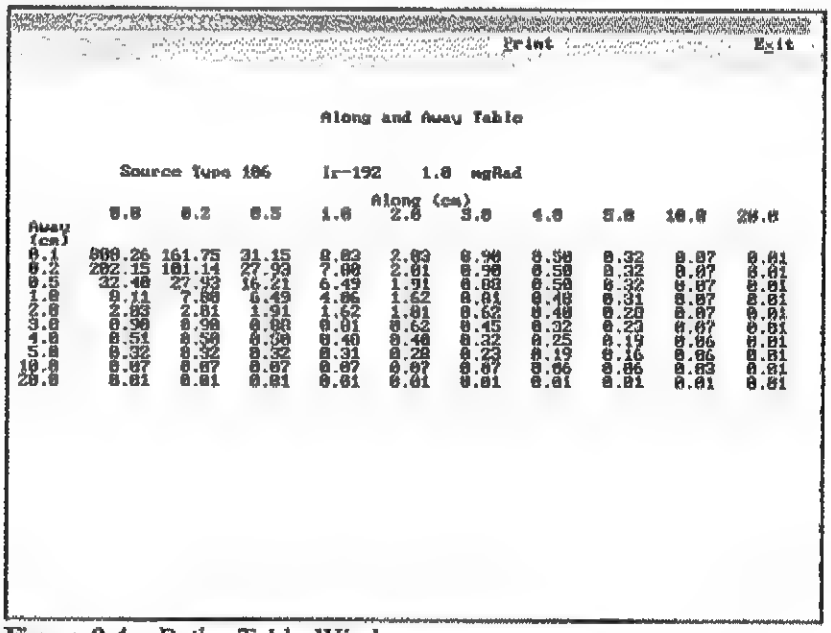


Figure 9.4 - Batho Table Window

Warning: Verify the entered parameters for each source type before clinical use. Parameters are verified by comparing the dose distribution calculated by Prowess using these parameters with measured or published dose distributions.

TEMPLATE ENTRY

The Brachytherapy Template edit program is used for entry and editing of the geometry or a brachytherapy template as well as default values for use of the template. To reach this option from the main menu, select Configuration, then Template Edit Program. The template edit window is shown in Figure 9.5.

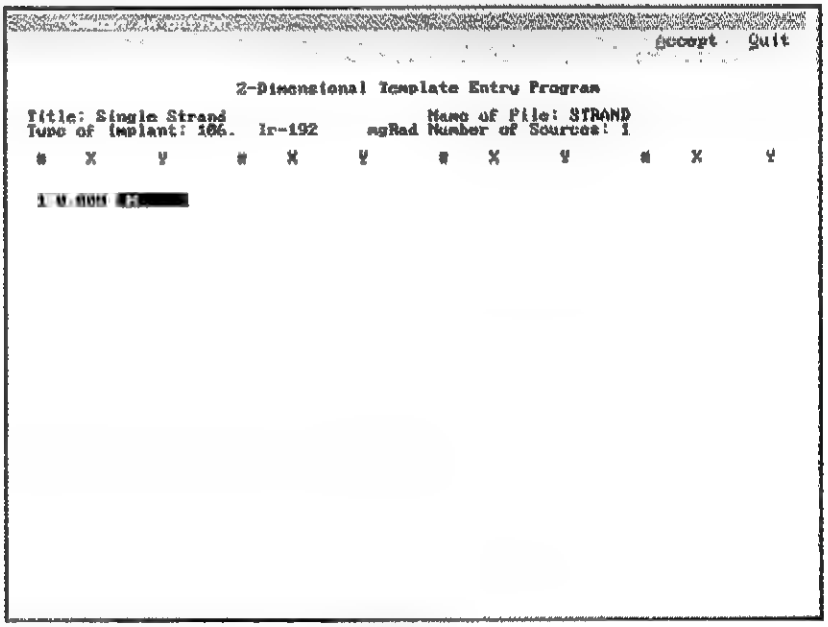


Figure 9.5 - Template Entry Window

To create a template, enter a file name, description, and seed type. Then, indicate the number of ribbons available and the (x, y) location of each ribbon. Select Accept or Quit after entry. All template files are located in the machine directory and have a .BTX extension.

TREATMENT MACHINE DATA ENTRY

OVERVIEW

The External Beam, Irregular Field, and Daily Dose Calculation modules must have the characteristics of a treatment machine available for calculations to be made. The PROWESS machine data entry module accommodates the needs of these programs by creating machine characteristic files. These files are stored on the hard disk in the C:\TPS3\MACHINE directory and are identified by a ".mch" extension.

A separate machine data file is created for each mode and energy available on each treatment machine. The keyboard, digitizer, and direct file transfer are available for machine data entry.

The properties of a megavoltage photon or electron beam are stored in the form of a set of data tables. Much of the process of calculating a dose is simply retrieving values from these tables. These tables can be one-dimensional such as peak scatter factor vs. field size. They can be two-dimensional such as scatter-maximum ratio vs. field size and depth. They can also be three-dimensional such as off-center ratio vs. field size, depth, and distance. In practice, a three-dimensional data set is treated as a group of two-dimensional data sets.

Only linear interpolation is used during table lookup. The calculation modules do no form fitting to or extrapolation from these data tables. What is entered here is what will be retrieved later. Thus, it is crucial that the data in these tables be correct, complete, and accurate. The purpose of this section of the manual is to explain how to access, fill, and manipulate these data tables.

MACHINE DATA NEEDED

The basic machine data needed for the External Beam, Irregular Field, and Daily Dose Calculation modules are listed below. Some of this data is measured directly and some is derived from other data. In some cases, alternatives as to how to determine this data are available, so this section should be read completely before making measurements.

SECTION TEN
Treatment Machine Data Entry

General Information

The general machine data consists of the following: Name of treatment unit, SAD or nominal SSD of treatment unit, depth of dose maximum (d_{max}), typical blocking tray transmission factor, gantry angle when the gantry is pointed at the floor, direction of gantry rotation which is taken to positive.

Central Axis Data

Tissue Maximum Ratio (TMR) and Scatter Maximum Ratio (SMR) data are generally calculated from measured and entered Percent Depth Dose (%DD) data. Depth dose data is typically measured for 3, 4, 5, 6, 8, 10, 12, 15, 20, 25, 30, and 40 cm square fields and this data is entered and used to calculate TMRs. If plotted curves are to be entered with a digitizer, the location of the phantom surface, zero level, and depth scale must be known. The best way to enter this data is using direct file transfer from a beam scanning system. TMR data must extend to zero field size and this zero area data can be extrapolated from finite field size data. TMRs can also be extrapolated to depths deeper than those for which measurements are available.

Off-Axis External Beam Data

Off Center Ratios (OCRs) must be measured from smallest to largest field widths for which plans are to be calculated. Up to 20 field widths may be entered. Suggested field widths are 3, 4, 5, 6, 8, 10, 12, 15, 20, 30, and 40 cm. One profile is required at d_{max} and four or more at other depths. All field sizes must be scanned at the same depths.

OCR profiles are needed for each wedge. Half beam blocks, split wedges, and other specially blocked fields are considered to be separate wedge types. The open field is designated wedge type zero. Different wedges need not be scanned at the same set of depths. Though not recommended, it is possible to calculate wedge OCR data from wedge shapes, open field OCR data, and the attenuation properties of the wedge. The central axis wedge factor for each wedge is required at each field width for which OCRs are entered.

Machine Output

Calibrated dose rate at nominal SSD and d_{max} is required for the reference field size. For Cobalt machines, the calibration date is needed. For all timed units, the timer error is needed. Output factor is measured as a function of field size at d_{max}. Output factors are normalized to 1.0 for the reference field size.

Radial Dependence of Beam Intensity

A diagonal scan is measured from the central axis to a field corner at the depth of dose maximum.

Radial Dependence of Beam Energy

The off-axis half value layer can be measured using good geometry attenuation in water. It can also be calculated from a sequence of scans at different depths.

Peak Scatter Factor vs. Field Size

The Peak Scatter Factor (PSF) is measured to be the ratio of the relative output measured in water at the depth of d_{max} and in air at the same location.

Virtual SSD

The virtual SSD is measured as a function field size based on a best fit to inverse square measurements. This data is entered for electron beams only.

Block Edge Transmission

The block edge profile must be measured for all blocking types used. It is measured at d_{max} for an open field and a blocked field.

MACHINE FILE INITIALIZATION

From the main treatment planning menu, select **Configuration** and then **Machine Data Entry**. To create a new machine file, enter the machine file name using at least six and not more than eight characters. Uppercase is not distinguished from lowercase. This file name entered will be displayed when selecting a machine from within the calculation modules. After creation, this file is available to all calculation modules. Press <Enter>.

When a new machine data file is created, all of the appropriate structures are created and access to these structures is provided through the buttons shown below. With certain restrictions, editing of the various data can be carried out in almost any order.

You are next prompted for the machine general information as described in the next section.

The next pop-up prompts for parameters needed to initialize all data tables. First, enter the maximum depth of your depth dose data in centimeters. This value is not generally important as most of the machine file entry options override it. However, if data is to be manually entered or digitized, an accurate value is needed.

Second, enter the maximum 2X/W OCR profile width. The units of 2X/W are dimensionless where X is the distance from the central axis to the profile location, W is the width of the beam at depth, and "2" divides the total width to give half width. Thus, 2X/W distance is the proportion of the distance from the central axis to the geometric beam edge at depth. Using this dimensionless quantity, the geometric edge of the beam is always at a distance of 1.0. For a 10 x 10 cm field size and a maximum 2X/W value of 1.5 at a nominal SSD of 100 cm and a depth of 50 cm, the profile scan must be at least 22.5 cm wide. A large maximum value provides for many data points outside the beam at the expense of resolution inside the beam. The default value of 1.5 is generally a good compromise.

Third, enter the number of profile depths that will be used for wedge zero (i.e., the open beam). There must be at least four depths, but five to seven are recommended. The profiles start at either the surface or at d_{max} and generally proceed to approximately 30 cm deep. Finally, enter the profile depths in centimeters (d_{max} must be included).

At the bottom of the screen is displayed the number of blocks and beam profiles for which data has been entered along with the number of wedges entered. The date on which the file was created is also shown on the screen. To save this data, select Accept.

The main machine data entry window is presented as shown in Figure 10.1.

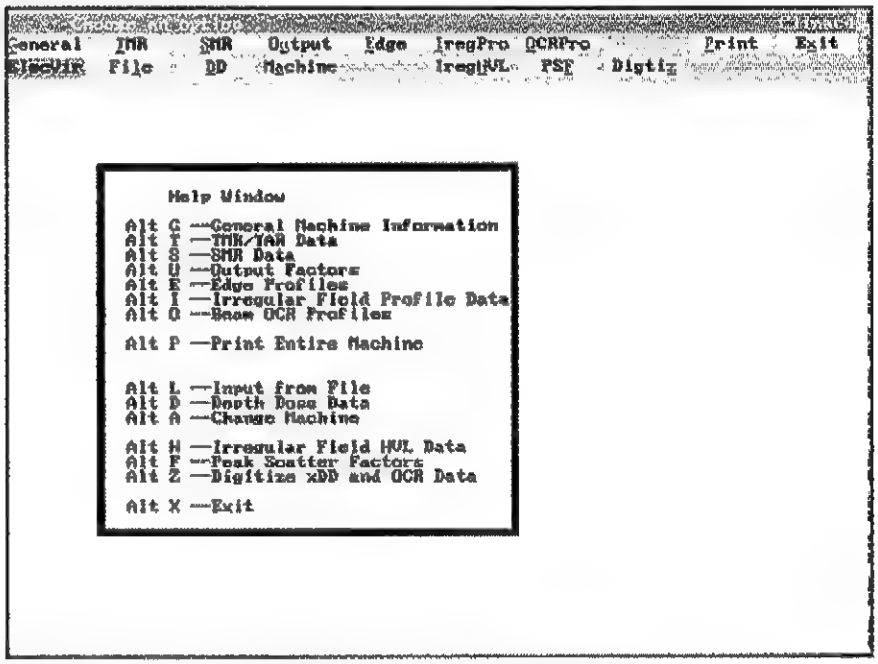


Figure 10.1 - Main Machine Data Entry Window

GENERAL DATA

General information can be edited by choosing General. It is prompted for automatically when a new machine is created. The general data edit window is shown in Figure 10.2.

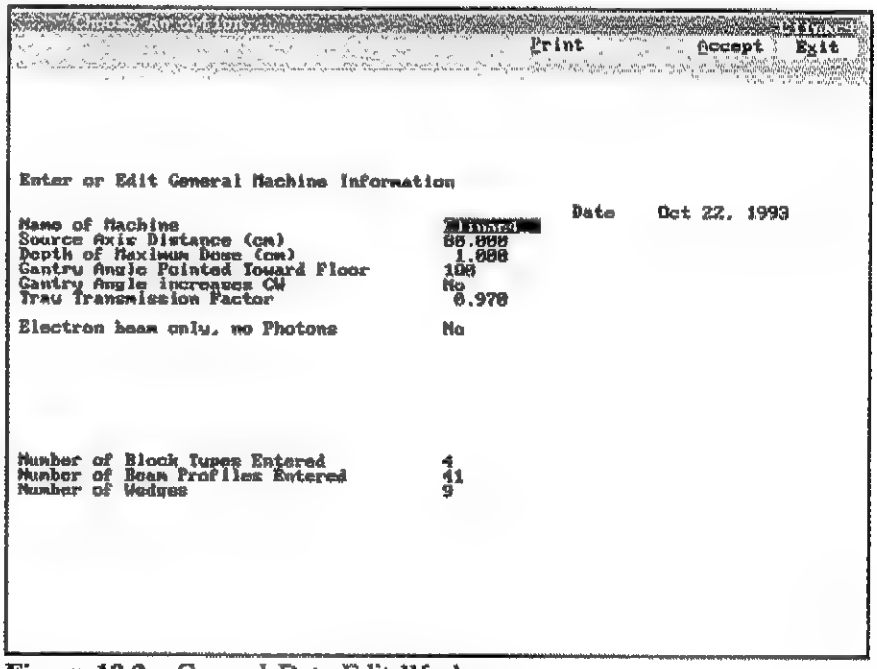


Figure 10.2 - General Data Edit Window

First, enter the name of the machine. It will appear on all printouts and may be the same as the file name. Second, enter the Source to Axis Distance (SAD) or nominal Source to Skin Distance (SSD). This is typically 80 or 100 cm. Third, enter the depth of dose maximum in centimeters along the central axis for a 10 x 10 cm field. Fourth, enter the gantry angle when the machine is pointed at the floor. Enter "Yes" or "No" to indicate whether the gantry angle indicator increases in the clockwise direction. Fifth, enter the most common blocking tray transmission factor. Finally, answer "Yes" or "No" as to whether this is an electron data set. When the entries are satisfactory, choose Accept.

CENTRAL AXIS DATA

From the machine data entry menu, central axis data may be examined by selecting TMR, SMR or DD. PROWESS uses the TMR and SMR tables for all teletherapy calculations. These tables are generally calculated from measured %DD data.

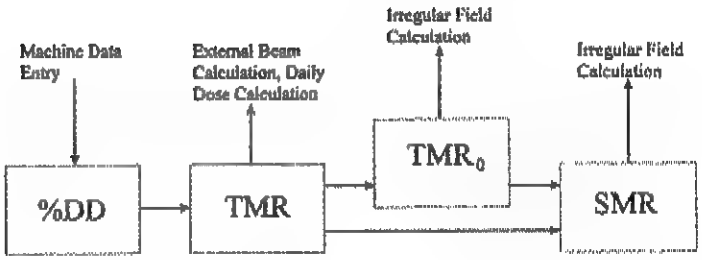


Figure 10.3 - Central Axis Data

Depth Dose

To access the %DD data edit window as shown in Figure 10.4 from Figure 10.1, choose **D**D. You will initially find an empty matrix with no field sizes and depths from 0 cm to the maximum depth specified during interpolation. Type in the depth dose data if desired. Ensure that as a field size is entered, a column (I Col 1) is inserted into your data set. Also, ensure that a valid field size label is entered at the top of each column.

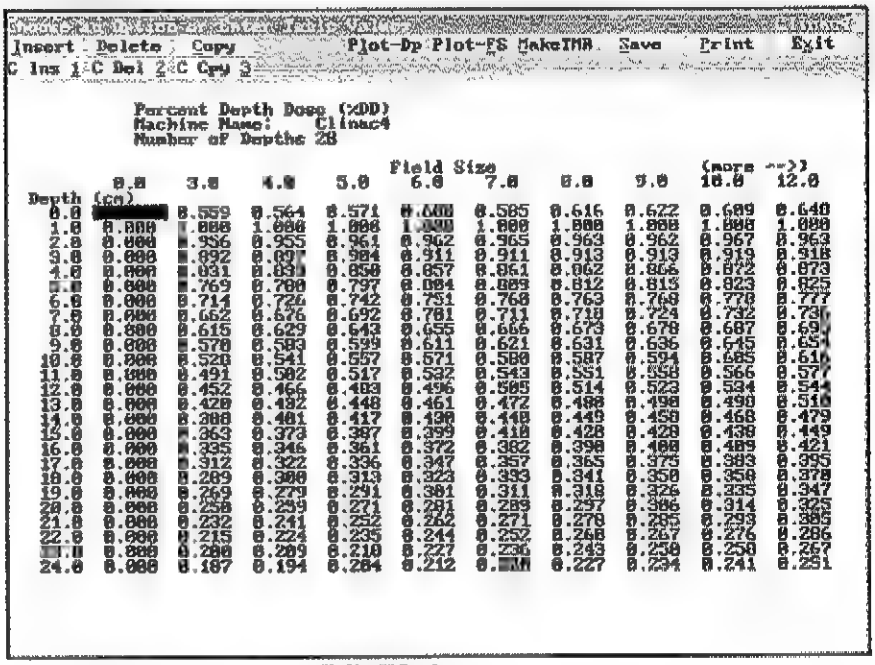


Figure 10.4 - %DD Data Edit Window

Generally, depth dose data is entered from files created by a beam data acquisition system.

%DD File Entry: Choose File from the main machine data entry menu. Choose the file type from the button bar shown in Figure 10.5.

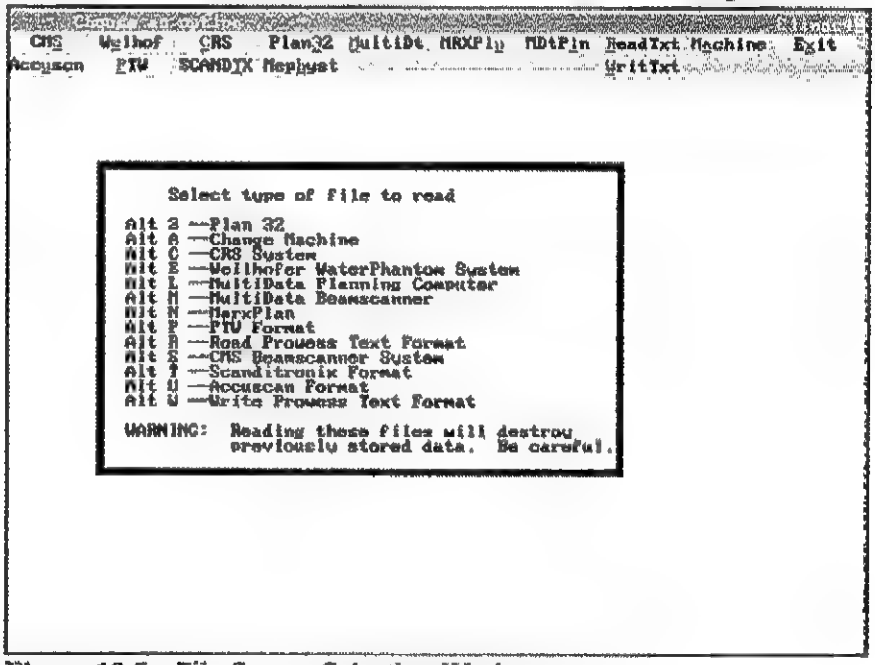


Figure 10.5 - File Source Selection Window

Select %DD entry from the buttons shown in Figure 10.5.

The TMR format should not be used as better results are obtained if TMRs are calculated from %DD.

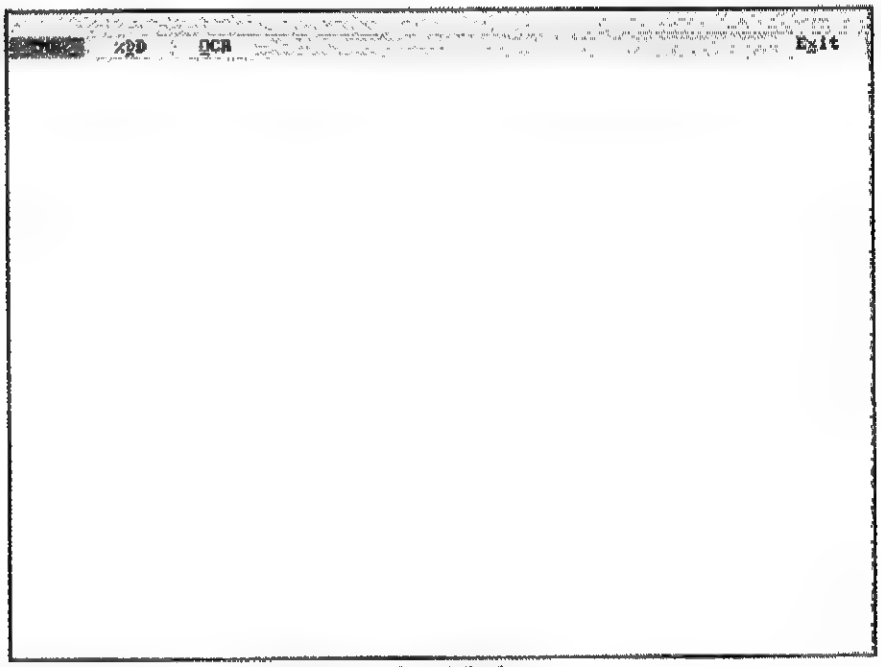


Figure 10.6 - Curve Type Selection Window

Enter the complete path and file name of the data to be entered; e.g., C:\TPS\ACCUSCAN\410.DAT.

Multiple files can be entered from the window shown in Figure 10.7.

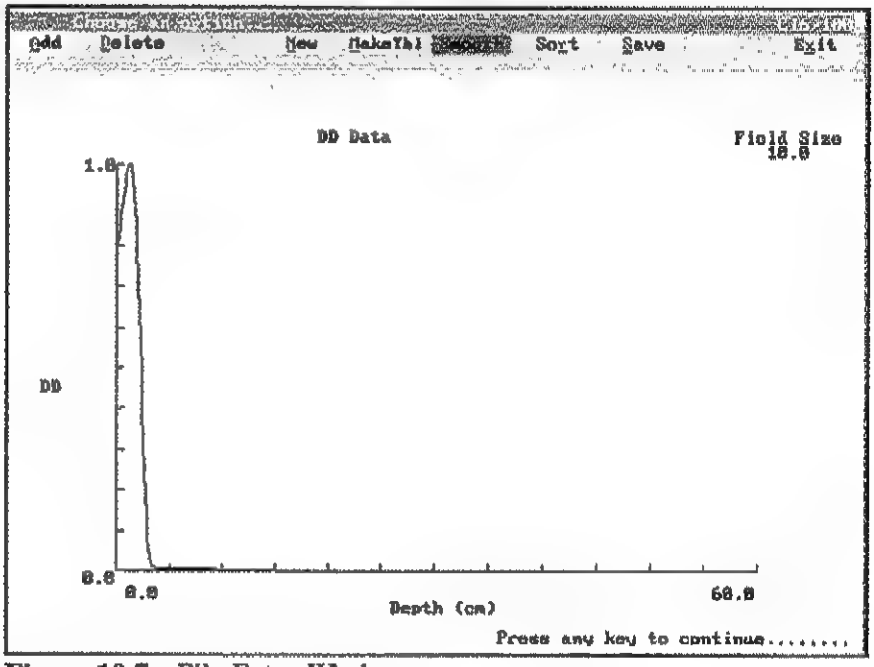


Figure 10.7 - File Entry Window

PROWESS only reads data files written by beam data acquisition systems in an ASCII format. The CRS and ACCUSCAN beam acquisition systems store their data in ASCII format, so no manipulation is necessary. Using the Scanditronix, MultiData, PTW, and Welhofer water tanks, only ASCII text file formats may be used. Refer to the user's manual for these items to determine how to store an ASCII text file. If problems are encountered, contact the beam scanner manufacturer. From the Multidata file format options, choose the comma delimited ASCII option, instead of the printer text file option.

Discrete Scanner Files: One %DD data entry procedure is used for all beam scanners except MultiData, Welhofer, and CMS. To begin, choose File, Accuscan (or some other name), and %DD options. An empty depth dose graph will appear on the screen. Add the depth dose data files for each field size. To enter the first field size, choose Add and then type in the exact drive path and name of the data file to be used (e.g., A:\DIRECTORY\filename.dat). Enter the field size of the data set. If the field size you enter does not match that specified in the data file, an error will occur. To override the field size in the data file, type <Enter>. ESCape will abort the entry.

Next, specify whether to normalize to d_{max} or to the maximum value of the curve. Generally, d_{max} should be used. If the file is read and the format is correct, a %DD scan will appear on the screen. The field size is shown on the right in the same color as the %DD displayed. Continue entering the remaining data files by repeating this procedure until all field sizes have been entered.

Each time Add is chosen, it will display the last path and file name. Change the name to the new %DD file. The program will add the default extension for the scanner. When a scan is entered at an existing field size, the previous scan is overwritten.

After all of the field sizes have been entered, the data may be saved by choosing Save. If they were not entered in ascending order, choose Sort, then Save. In order to move this data into the depth dose matrix, choose MakeTbl. A warning is given that this overwrites existing data. Type <Enter> and the data will be interpolated and entered into the depth dose table overwriting all existing %DD data.

Review the data set by returning to the main data entry menu and choose DD. The entered data is shown. Notice that the zero field size is blank.

Combined Scanner Files: MultiData, Welhofer, and CMS files are entered using a different procedure. For MultiData and CMS, ensure that the depth dose data has been combined into one file and saved in comma delimited or ASCII format. For Welhofer, the ASCII files must be stored in a single directory. To enter the depth dose, choose the type of scanner, the depth dose option, then give it either the name of the directory or the name of the composite data file where the data is stored. The program will read the data file and put it directly into the depth dose matrix. Individual depths cannot be entered easily from the Multidata scanner. With CMS and Welhofer, one may be entered at a time and appended to the %DD file.

TMR After the %DD values have been entered, the TMR table can be calculated from the %DD table. If this is an electron machine, ensure that the virtual SSDs for all field sizes and energies have been entered. PSFs are not used in calculating TMRs from %DD.

There is a limitation on the field size conversion from depth dose to TMR. When a TMR table is generated from the depth dose data, the

smallest field size entered will be deleted. If this field size is needed, copy the column (C Col 2) for the smallest field size, re-label that field size to 1.0 cm less than the actual field size (e.g., 4.0 is copied to 3.0 cm). If copying this column creates an unacceptable data error, then manually extrapolate %DD values from the smallest field size to 1 cm smaller.

Save the %DD table before making the TMR table. To make the TMR table, choose MakeTbl. Existing TMR data will be overwritten. PROWESS warns of this and asks for confirmation. Confirm by typing <Enter> or press ESCape to abort. Delete the extra column that was added in the %DD data and resave the table.

Examine the new TMR table by exiting the %DD table and choosing TMR. When TMR is selected, the window appears as shown in Figure 10.8.

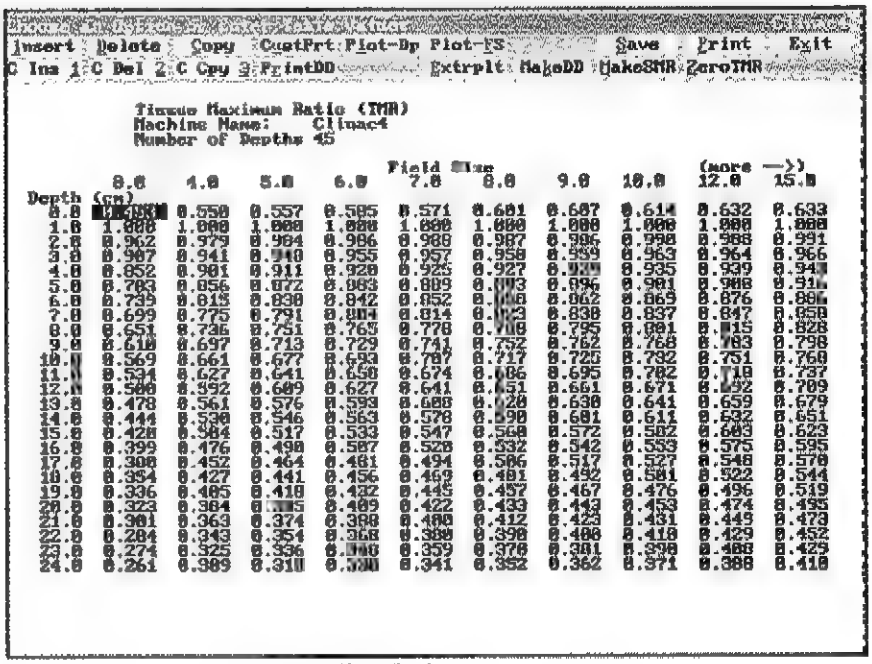


Figure 10.8 - TMR Data Edit Window

Select Plot_Dp to plot on the screen in a depth dependent format as shown in Figure 10.9.

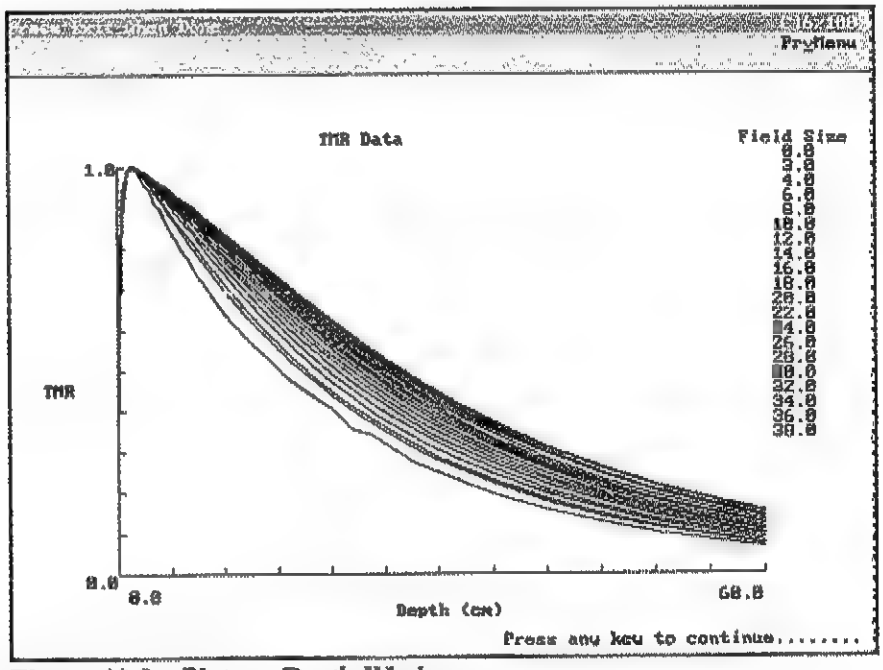


Figure 10.9 - Plot vs. Depth Window

Select Plot-FS to plot on the screen in a field size dependent format as shown in Figure 10.10.

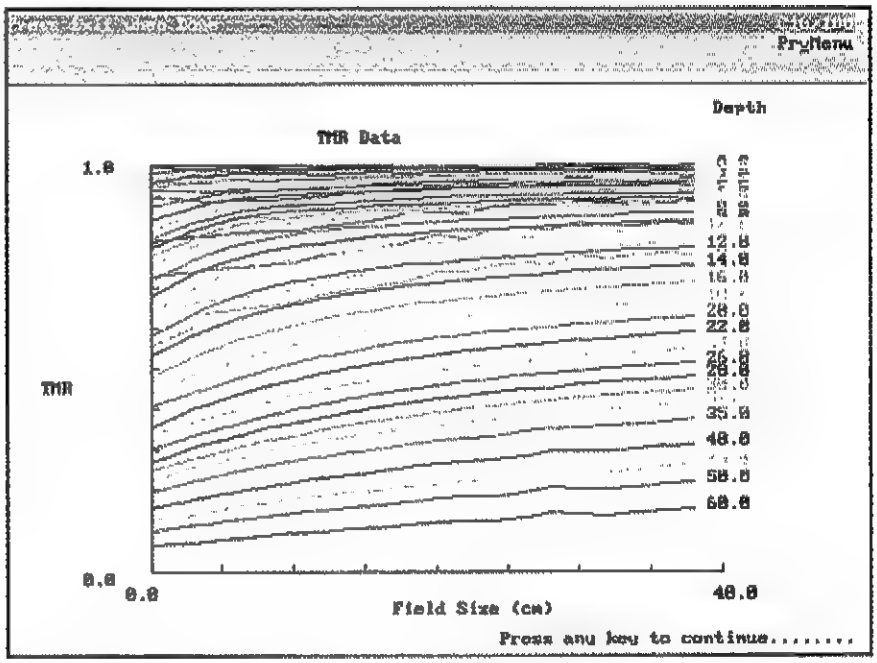


Figure 10.10 - Plot vs. Field Size Window

The TMR data must be extrapolated to depths as thick as the largest patient to be treated. Choose Extrapolt to extrapolate the data. This procedure fits the last 15 cm of the measured data to an exponential function and extrapolates the TMR to fill the matrix (50 depths). If the last depth is not large enough, hand extrapolate the data and enter this data into the last depth position. For electrons, simply append a depth of ~50 cm to the end of the TMR table with values of zero. Spacing of depths does not have to be equal, so depths may be concentrated in the build up region and expanded near the end of the table.

For photon machines, zero area TMR data must be entered. To calculate zero area TMRs from finite area TMRs, choose ZeroTMR. Ensure that there are zero depth entries for all field sizes. Plot the data on the screen by choosing Plot-FS or Plot-Dp and ensure that the data is acceptable. When plotting as a function of depth, a new blue line (the zero field size) should be below all other curves and follow the general shape of the curves. When plotting data as a function of field size, the fit may or may not be good. It may be necessary to go back and hand extrapolate some of the data until the curve is acceptable. Of course, the zero TMR may be entered by hand from hand measured or generated data. Once the TMR table is satisfactory, save and print that table.

SMR The SMR table is made from within the TMR function. To calculate the SMR table, choose MakSMR. This procedure will overwrite existing SMR data. Again, confirmation of the overwrite is necessary. To look at the SMRs, exit the TMR table (Quit) and choose SMR. The table of SMR's will be shown on the screen as in Figure 10.11.

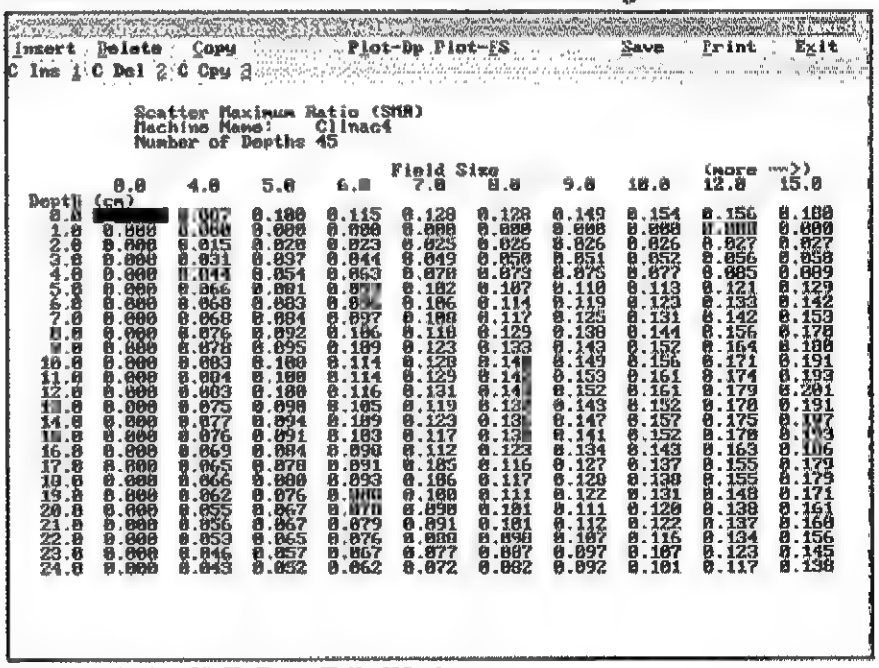


Figure 10.11 - SMR Data Edit Window

The table contains the SMRs for round field sizes where the field size shown is the diameter in centimeters. Plot this data by choosing Plot-FS or Plot-Dp and ensure that it is acceptable. If SMR is plotted as a function of field size, the curves may not be completely smooth. If they are very jagged, go back and recheck the TMR data. If all the SMR values for certain field sizes are jagged, this is a result of the zero TMR data not being smooth. Edit these zero area TMR values and then recalculate the SMR table. Notice that the largest field size in the SMR table is the largest field size in the depth dose table. If field sizes greater than this diameter are needed, (e.g., for extended SSD treatments), a larger field size may need to be calculated. Do this by copying or hand extrapolating the column (C Col 2) of the largest field size to a 50 x 50 cm field size and edit the field size. Since SMR becomes asymtotic at large field sizes, hand extrapolation is probably not necessary.

OFF-AXIS EXTERNAL BEAM DATA

Open beam profile data may be entered, edited, and displayed by selecting QCRPro. The data is entered as lateral profiles at five or more depths and several field sizes. Generally, the first profile is at d_{max} and the remaining depths are spaced at intervals of 5-8 cm below d_{max}. The data is stored in the dimensionless 2X/W distances. Conversion to 2X/W coordinates is made automatically.

Entry begins with display of the wedges, names, field sizes, and field size minima and maxima. A new wedge can be added or an existing wedge can be deleted from the window shown in Figure 10.12.

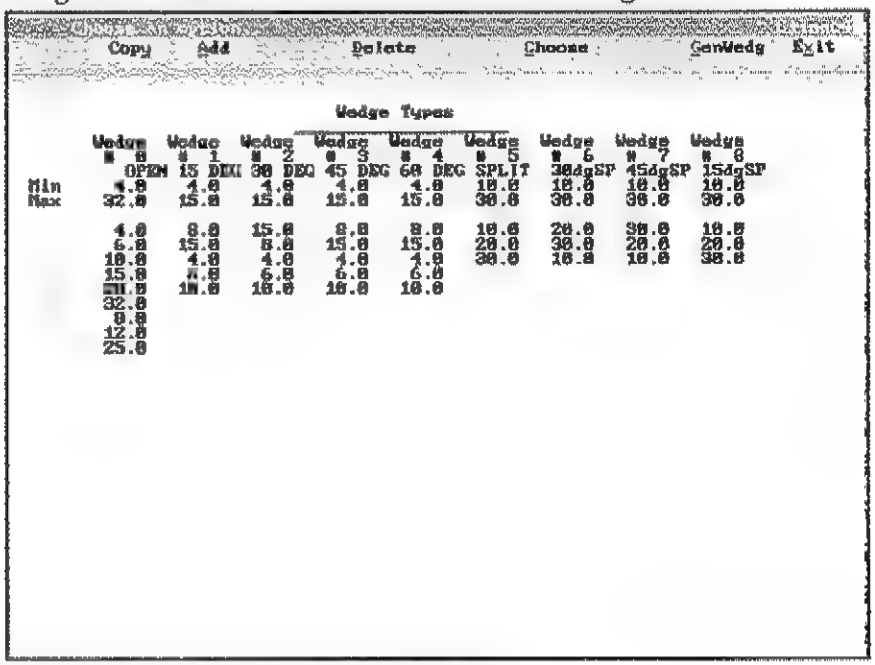
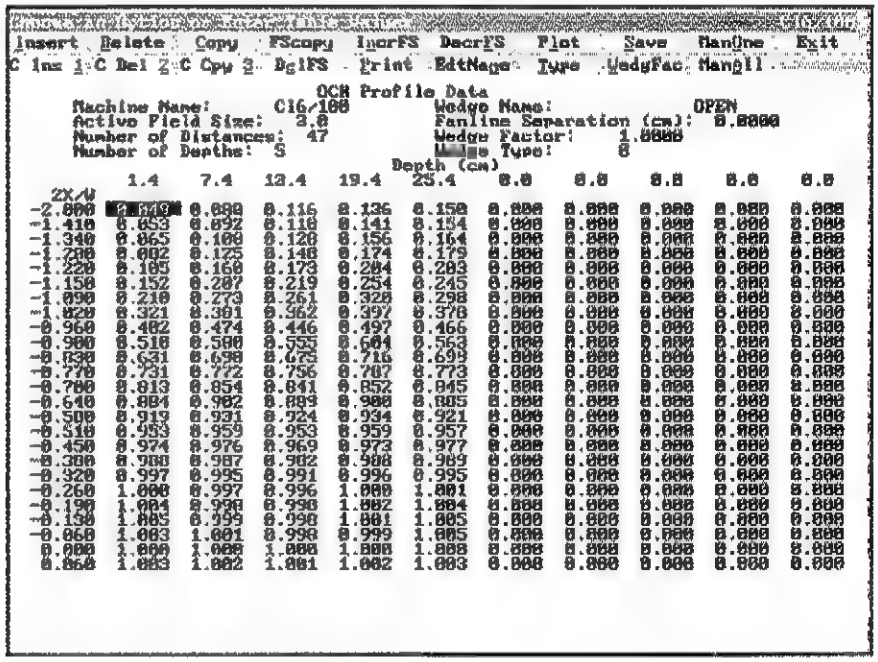


Figure 10.12 - Wedge Selection Window

Choosing a wedge brings up a table with the wedge's OCR values as shown in Figure 10.13.



Insert Delete Copy FSCopy IncrFS DecrFS Plot Save ManOne Exit
C Ins 1 C Del 2 C Cpy 3 DelFS Print EditName Type WedgFac ManAll

OCR Profile Data

Machine Name: C16/100 Wedge Name: OPEN
Active Field Size: 3.0 Fanline Separation (cm): 0.0000
Number of Distances: 47 Wedge Factor: 1.0000
Number of Depths: 5 Wedge Type: 8

2X/W \ Depth (cm)	1.4	7.4	12.4	19.4	25.4	0.0	0.0	0.0	0.0	0.0
-2.000	0.000	0.000	0.116	0.136	0.150	0.000	0.000	0.000	0.000	0.000
-1.410	0.053	0.092	0.118	0.141	0.154	0.000	0.000	0.000	0.000	0.000
-1.340	0.065	0.100	0.120	0.156	0.164	0.000	0.000	0.000	0.000	0.000
-1.280	0.002	0.125	0.140	0.174	0.179	0.000	0.000	0.000	0.000	0.000
-1.220	0.105	0.160	0.173	0.204	0.203	0.000	0.000	0.000	0.000	0.000
-1.150	0.152	0.207	0.219	0.254	0.245	0.000	0.000	0.000	0.000	0.000
-1.090	0.210	0.273	0.261	0.320	0.298	0.000	0.000	0.000	0.000	0.000
-1.020	0.321	0.301	0.362	0.397	0.378	0.000	0.000	0.000	0.000	0.000
-0.960	0.402	0.474	0.446	0.497	0.466	0.000	0.000	0.000	0.000	0.000
-0.900	0.518	0.500	0.555	0.604	0.563	0.000	0.000	0.000	0.000	0.000
-0.830	0.631	0.690	0.675	0.716	0.699	0.000	0.000	0.000	0.000	0.000
-0.770	0.731	0.772	0.756	0.707	0.773	0.000	0.000	0.000	0.000	0.000
-0.700	0.813	0.854	0.841	0.852	0.845	0.000	0.000	0.000	0.000	0.000
-0.640	0.884	0.902	0.889	0.900	0.885	0.000	0.000	0.000	0.000	0.000
-0.580	0.919	0.931	0.924	0.934	0.921	0.000	0.000	0.000	0.000	0.000
-0.510	0.953	0.959	0.953	0.959	0.957	0.000	0.000	0.000	0.000	0.000
-0.450	0.974	0.976	0.969	0.973	0.977	0.000	0.000	0.000	0.000	0.000
-0.380	0.988	0.987	0.982	0.988	0.989	0.000	0.000	0.000	0.000	0.000
-0.320	0.997	0.995	0.991	0.996	0.995	0.000	0.000	0.000	0.000	0.000
-0.260	1.000	0.997	0.996	1.000	1.001	0.000	0.000	0.000	0.000	0.000
-0.190	1.004	0.998	0.998	1.002	1.004	0.000	0.000	0.000	0.000	0.000
-0.130	1.005	0.999	0.998	1.001	1.005	0.000	0.000	0.000	0.000	0.000
-0.060	1.003	1.001	0.998	0.999	1.005	0.000	0.000	0.000	0.000	0.000
0.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000
0.060	1.003	1.002	1.001	1.002	1.003	0.000	0.000	0.000	0.000	0.000

Figure 10.13 - OCR Edit Window

Select Plot to plot the OCRs on the screen as shown in Figure 10.14.

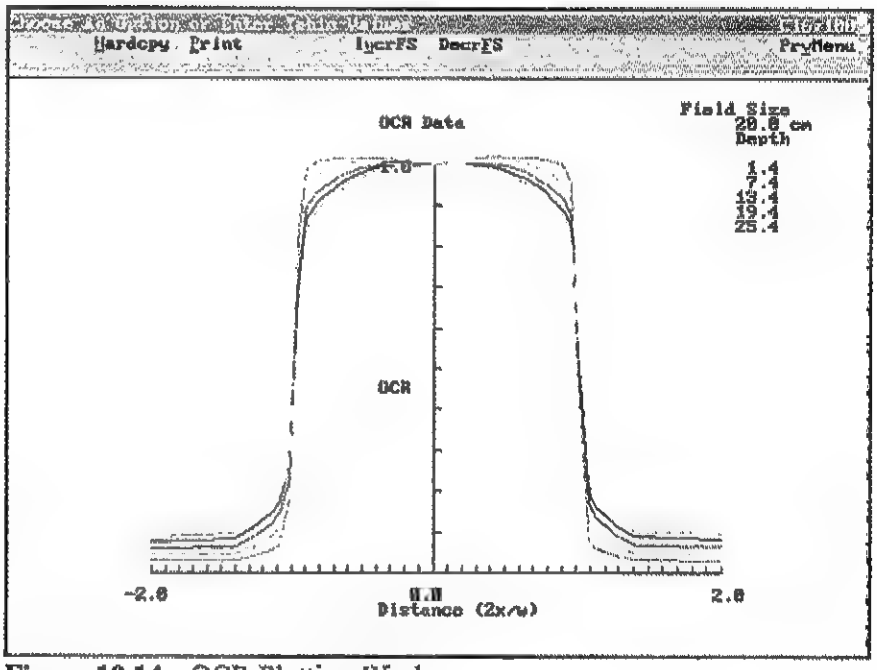


Figure 10.14 - OCR Plotting Window

Editing or manipulating the profile data can be done for one or all depth profiles simultaneously. Choose ManOne to change only the current depth or ManAll to change all depths for that field size. Choosing either brings up the window shown in Figure 10.15.

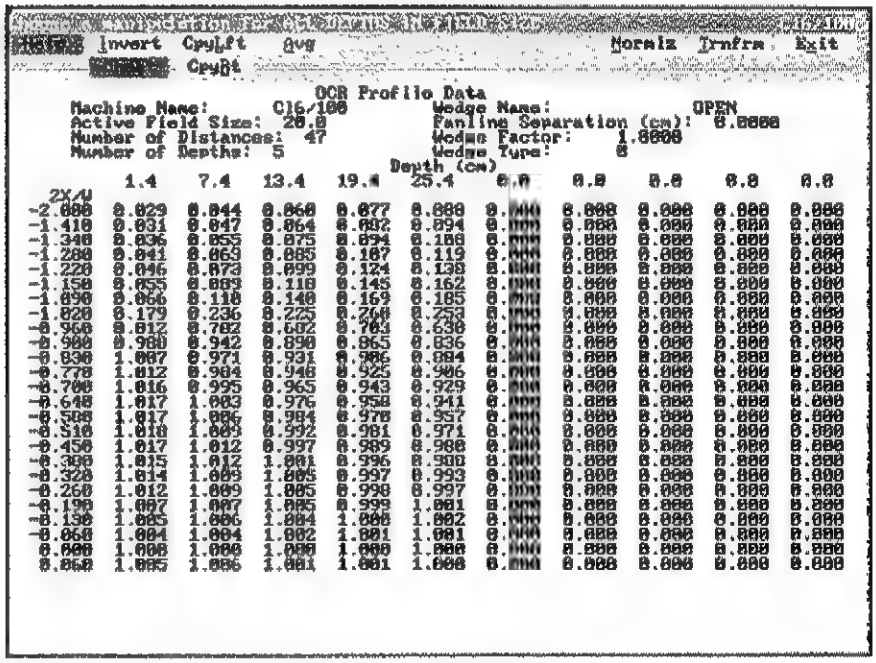


Figure 10.15 - OCR Manipulation Window

OCR Calculation

This procedure multiplies a wedge transmission profile by the open field size OCRs for each depth and field size. This is an approximate entry procedure replacing measured data. Adjust the shape of the wedge profile to achieve the appropriate shape of wedge profiles as necessary. Choose GenWedg to get to the window shown in Figure 10.16.

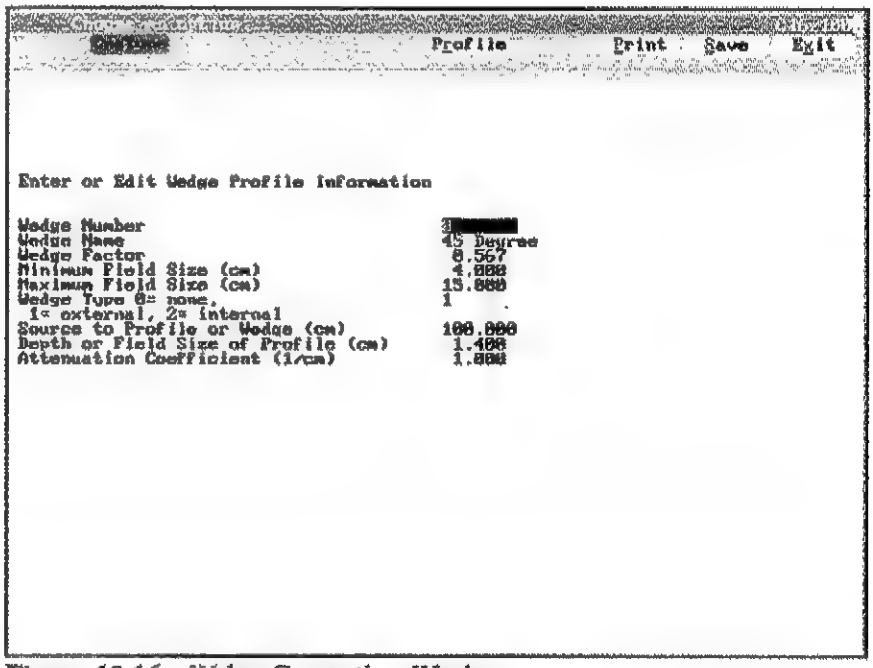


Figure 10.16 - Wedge Generation Window

Select Profile to enter the wedge shape as shown in Figure 10.17.

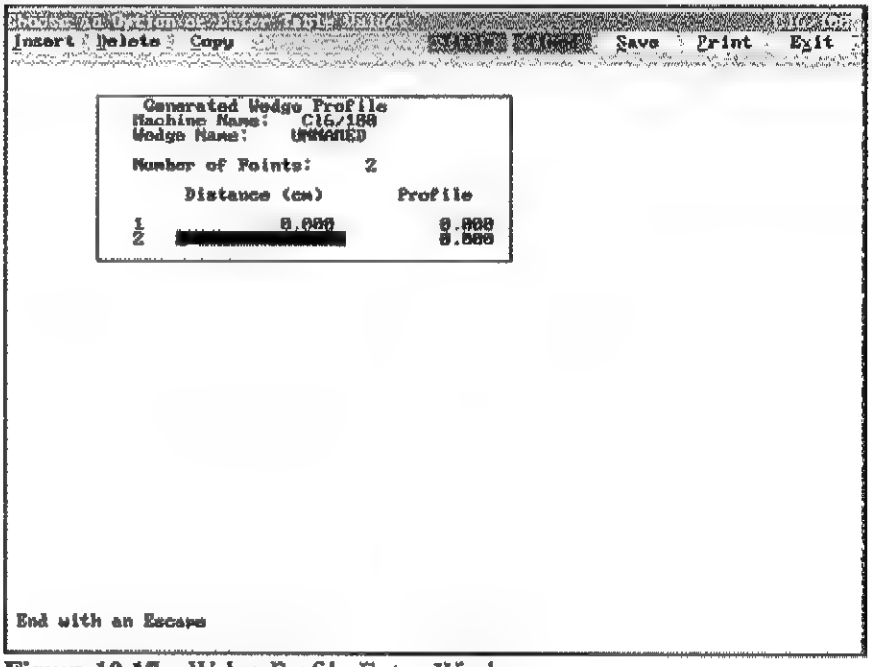


Figure 10.17 - Wedge Profile Entry Window

The attenuation coefficient must be specified for the wedge material. Once entered, two new options are shown, MakWedg and Profile. Enter the shape of the profile at the source to wedge distance specified. Once the profile is entered the wedge may be created and saved. Choose wedge profile, plot and verify it. This wedge profile data is saved.

This technique is not recommended as better results are obtained using measured data.

OCR Measurement

OCRs are measured across each field width at each depth and generally normalized to 1.000 on the central axis as shown in Figure 10.18.

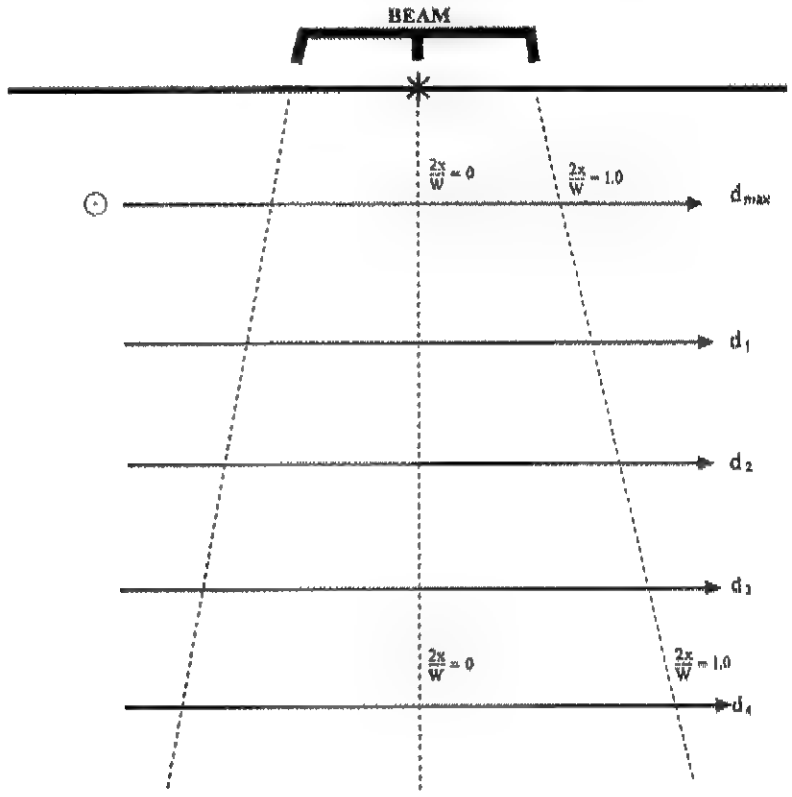


Figure 10.18 - OCR Measurement

Verify that the depths of the profiles for each of the wedges are correct. It will not be possible to enter wedge data unless the profile depths match for each wedge. The depths for each different wedge may be different, but all the profiles for a single wedge must be the same.

OCR Entry

Create the number of wedges that are going to be entered into this data set. Typically, this is four additional wedges (15°, 30°, 45°, and 60°). If there is an asymmetric collimator or a beam splitter, treat this as a wedge and add a fifth wedge type. If beam split wedges are used, create a new wedge for each of these configurations. A maximum of 10 wedges can be entered in a data set including the open field. The Add command is used to create these additional wedges. Once Add has been chosen, a blank wedge will appear on the screen. Choose Save and Quit. Repeat this process until all empty wedge profiles have been created.

Choose a wedge for editing. The wedge OCR table is presented.

All of the data in this table may be edited. Use the arrow key to move through the table. Remember, changing the depths and distances affects all field sizes within this wedge set. Depths and distances must be specified before profiles may be digitized or data entered from a file. After making changes to data files, press Save to save changes. To edit depth or off-axis distance, use the arrow keys to move to the desired position. Type in the new value. Changes to these values affect all field sizes for that wedge. Save makes these changes permanent.

Wedge profiles are entered with the maximum value displayed on the right side of the screen (i.e., the OCRs are greater at positive distances than negative distances). If it is reversed, finish entering all data and press ManAll, then Invert. This will reverse the orientation of the wedge.

If the profile measured depths within a wedge are not the same, you can compensate by changing the depths, saving them, entering the data for that particular field size, saving it, going back and editing the depths, saving them, entering the profiles for the next field size, and so on. The profiles are frequently slowly varying with field size and depth. Though this technique is not recommended, misregistration of depth will generally cause only minimal effect on the profile shape as all the data is normalized to a dimensionless distance parameter 2X/W.

The profile data is most commonly entered from a beam data acquisition systems.

OCR File Entry: To begin OCR file entry, choose File from the Machine Entry menu.

Choose the file type by name (e.g., Accuscan). Then choose OCR to signify profile data entry. Identify the wedge number to be entered. If this is the open wedge, enter zero. Displayed on the screen is an X-Y axis with OCR on the vertical axis displayed from 0-1 and the distance on the Y axis extending from -30 cm to +30 cm. To enter a profile, choose Add and enter the name of the file desired (e.g., C:\ACCUSCAN\347.DAT). Verify the field size. The profile or profiles will be displayed on the screen, all normalized to 1.0 on the central axis.

If this is a CRS or Accuscan scanner and there is one profile depth per file, enter all of the file names and build the complete profile set for that field size by choosing Add each time. When all of the profiles for that field size are entered, choose MakeTbl and verify. The profile set will be added to the OCR profile for the wedge number and field size specified. The order of field size entry is unimportant as sorting is handled internally by PROWESS. To enter another field size, choose New to clear the screen. Repeat the procedure described above for each field size until all are entered. Be sure to choose MakeTbl, for each field size to save it before entering a new field size.

After entering the first profile, verify the data. To do this, select Quit until reaching the Main Machine entry menu. Choose OCRPro. Select the wedge and field size to view. Plot the profile with Plot. Ensure that the data is acceptable before proceeding to the next field size or wedge. To enter the remaining wedges, follow the same procedure, only choose the appropriate wedge number and appropriate files to enter this wedge profile data.

After entering all of the wedge profiles, add the remaining wedge data. To do this, choose OCRPro. Displayed on the screen is a listing of all of the profiles which have been added to the wedges. The minimum and maximum field sizes are still 10. That means that this data has not been processed or saved and the minimum and maximum have not been registered in the data set. Each of the wedges must be processed.

Choose wedge zero by selecting Choose and "0" for wedge number. The 10 x 10 field size will be displayed on the screen. Plot this wedge profile by choosing Plot. Ensure that the data is acceptable and press ESCape. Edit the remaining data for the wedges. First, enter the name of the wedge by pressing EditName and type in OPEN. This entry titles all field sizes for this wedge. Next, enter the wedge factor (WedgFac). For the open wedge, the wedge factor is one for all wedges and field sizes. Plot the profile on the screen and increment (IncrFS) and decrement (DecrFS) through all field sizes verifying the shape of the curves. If data points are found which are in error, manually edit them. To edit, select Quit to exit from the plot. Using the arrow keys, move to the location of the error and correct it. Replot the data to verify your entry, then save. After reviewing all the field sizes again, Save the final version. All field sizes are saved and the maximum and minimum field sizes are registered. Press ESCape to see the registered minimum and maximum field sizes and a name that has been entered for this wedge. Proceed to edit each of the wedge data sets entered.

More editing is required for the other wedges. Choose wedge one (i.e., 15° wedge) and plot it on the screen. The data may have been entered with the peak of the wedge data (thin end of wedge) on the left side of the screen. PROWESS requires that the peak be on the right side of the screen. Increment through all of the field sizes to make sure that they are all consistent as one might be reversed from the others.

To reverse or renormalize all the profiles in a field size, choose ManAll. To reverse the wedge orientation, choose Invert. Confirm the result by plotting the data. Increment through all of the field sizes and perform the same procedure. ManAll applies to all depths for this single field size, it does not apply to all field sizes within this wedge. The function ManOne modifies only the active depth.

Enter the name of the wedge and the wedge type. The type specifies the screen display. A normal wedge is type one, an open field size is type zero, a beam splitter is type two, and a beam split wedge is type three. The type and the name apply to all field sizes in this wedge and must be entered only once.

Increment through each field size and enter the appropriate wedge factor for that field size. For those machines where the wedge factor does not vary with field size, the wedge factor must still be entered for all field sizes.

Digitizing OCR Data: OCR data may be entered using the digitizer. The depth increment is dependent upon the initial data entered when the machine was first created. All OCR data for a wedge must be at the same depth for all field sizes. However, they may be different for each wedge. The lateral increment spacing for each field size must be consistent. PROWESS automatically modifies data to coincide with these principles.

Prepare the data by having all the OCR curves in the same format. The central axis zero radiation level must be marked along with a point to the right on the zero level. Mark the maximum of the curve on the central axis.

When the data is ready for entry, select Digitiz from the main machine entry menu and OCR from the sub-menu. Choose the wedge number and field size for the entry. The program then displays the depths of the profile to be entered. Press any key to continue. See Figure 10.19.

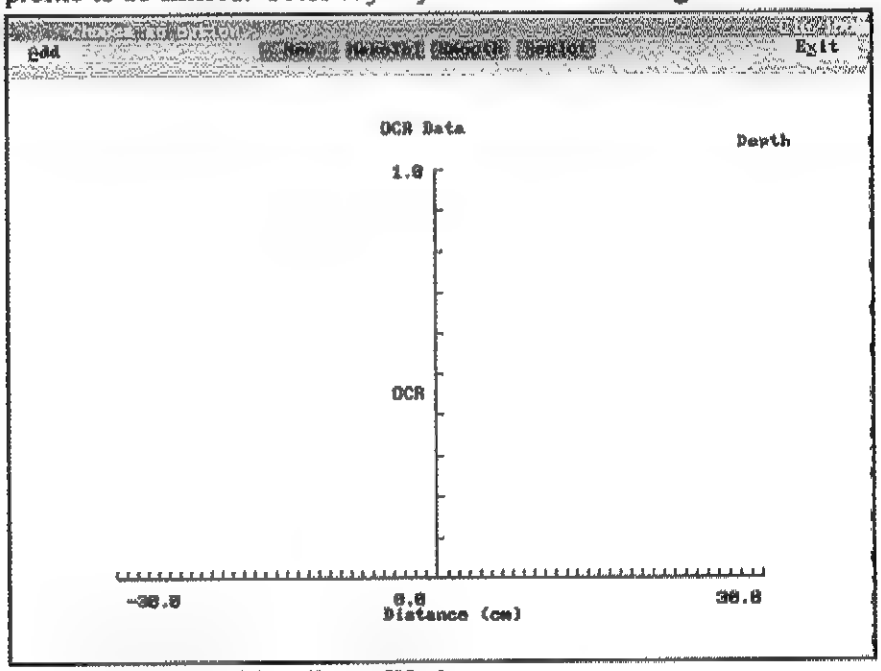


Figure 10.19 - Digitizer Entry Window

Start the procedure by selecting Add. Enter the magnification and calibrate the digitizer by entering points "U" and "L". Touch the stylus to the origin on the central axis profile and a point to the right of the origin on the zero radiation level. This orients the graph to the

digitizer. Touch the stylus to the maximum of the curve on the central axis. This normalizes the curve to 1.0 on the central axis. Then trace the profile from left to right. The program will continuously enter data until the stylus is lifted from the graph. Touch **End** to complete that profile. Enter all of the profiles in succession until all of the depths have been entered.

To restart the entry, touch **R**estart on the digitizer. If, during entry of a curve, correction of misentered data is necessary, touch **Delete** until the bad data is erased. Continue entering data from that point until the curve is completed. To change curve number, touch **Change** and enter the new curve number.

When all the curves have been entered, the menu returns. The curves may be erased and restarted by selecting **N**ew. To store the data in tabular format, choose **M**akeTbl.

To enter the next profile, select **N**ew and **A**dd. Enter the data and store the results. Exit the function by selecting **Q**uit or **ESC**ape.

Check the data entry by selecting **O**CR from the main machine entry menu. Select the wedge number and profiles just entered. Plot the data. The data may be edited, renormalized, or flipped. Examine its shape as necessary from this function. **S**ave the data after editing is complete.

Split Wedges

When a beam split wedge is entered into a field, there are three effects on the dose to a point under the wedge: (1) the beam is attenuated by the wedge, (2) the beam is hardened by the wedge, and (3) there is a loss of scatter.

For an unsplit wedge, transmission is separated into two components. The OCR gives the relative dose normalized to the central axis and wedge factor relates the central axis to the open field. Due to large dose gradients, an absolute measurement at the central axis of a beam split field is of little value and should not be used for normalization.

Loss of scatter is generally considered through the use of effective field sizes in looking up TMR values. However, this technique becomes more uncertain as blocking is increased and would not yield the best answers near the block edge in the beam split wedge case.

PROWESS can handle beam hardening by wedges by renormalizing OCR profiles in such a way that these factors are considered. The first step is to choose a measurement point inside the wedged part of the beam at d_{max} which is away from the split edge. Approximately 2 cm should work well though 1 cm for small field sizes may be necessary. Measure the output at this point with and without the split wedge and find the ratio (value between zero and one). This ratio includes the effect of loss of scatter and wedge transmission and it is the desired OCR at that point. Measuring this factor at all scan depths will include the effect of differential hardening. Ratios are measured at all field sizes for which profile scans exist.

To normalize an OCR profile for a given field size and depth, use the normalization option under ManOne. If differential wedge hardening is neglected, ManAll can be used to normalize the whole field size. First, determine the OCR at the calculation point from the 2X/W table. Interpolation may be required. Geometric projection into the tabulated coordinate system will by required. Divide that OCR by the desired OCR (the measured ratio) and the result (generally between one and four) is the normalization constant. The use of a spreadsheet program (if available) can be helpful.

It is possible to do this type of renormalization for unsplit wedge data as well if you want to integrate wedge factors and beam hardening into the OCR data.

MACHINE OUTPUT

Output factors may be entered for up to 25 field sizes. These factors are specified at d_{max} and machine's nominal SSD. Select Output and the program displays a table of the equivalent square output factors as shown in Figure 10.20.

Fill in the table with equivalent square field sizes (cm) and the relative output factor for each field size. It is customary to normalize the output factor data such that it is 1.000 for a 10 x 10 cm field.

Use the Insert function to add the number of field sizes to be entered up to a maximum of 25 field sizes. Start from the smallest field size and proceed to the largest field size in ascending order.

Select the Timed option to specify whether or not the unit is timed and, if it is timed, what the shutter factor is. Also, enter the calibrated dose rate and calibration date for a cobalt unit. Most modern linear

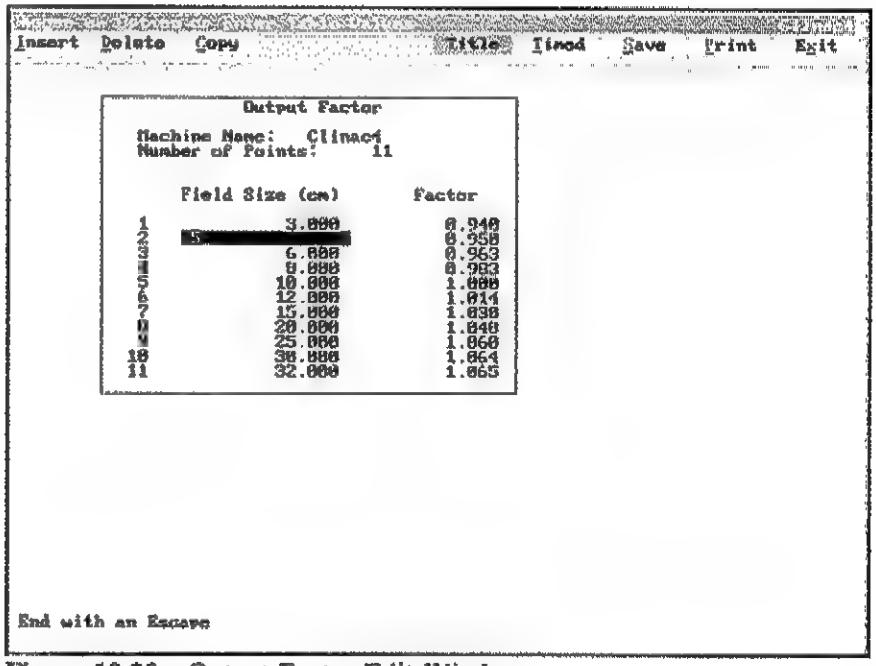


Figure 10.20 - Output Factor Edit Window

accelerators will be specified as non-timed with a calibrated dose rate of 1.000 cGy/mm and no shutter factor.

Calculations made by PROWESS expect the calibrated dose rate to be specified at d_{max} and the nominal SSD. See Figure 10.21. Additional corrections may be required for a unit that is not calibrated this way.

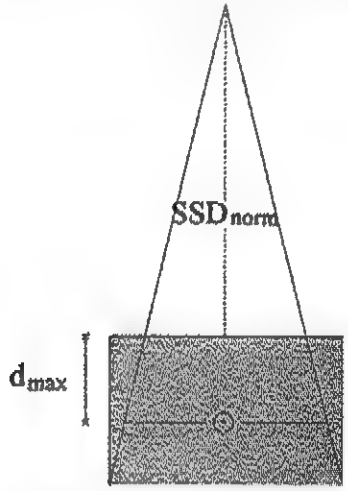


Figure 10.21 - Calibration Setup

RADIAL DEPENDENCE OF INTENSITY

Off-axis factors characterize the non-uniformity of the field. They are measured at d_{max} from the central axis along the diagonal of the largest field. Enter this data by selecting IregPro. Selecting this option brings up the window shown in Figure 10.22.

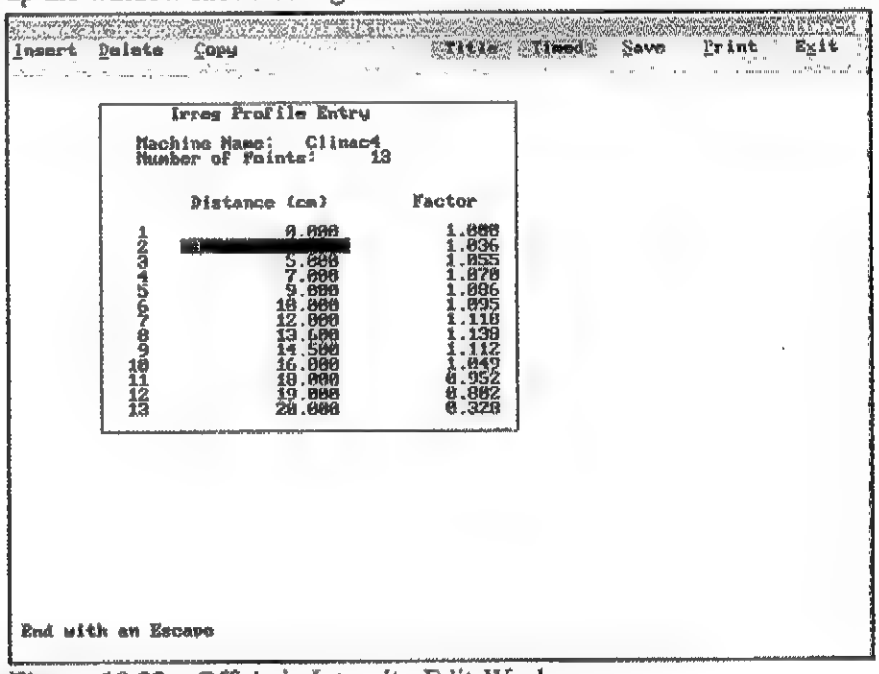


Figure 10.22 - Off-Axis Intensity Edit Window

Up to 25 points may be entered. For most linear accelerators, the off-axis factor will increase as the distances increase away from the central axis and then will decrease dramatically into the corner of the largest field. The off-axis data is normalized to 1.000 on the central axis.

RADIAL DEPENDENCE OF ENERGY

The Irregular Field calculation program includes a correction for off-axis spectral changes (softening) caused primarily by the varying thickness of an accelerator's flattening filter. This requires tabulated values of the beam's first-scatter half value layer in water measured under good geometry. The units of the HVL are cm H_20.

Good geometry HVL can be determined by measuring the transmission of a beam through a slender column of water placed along a ray line using an ionization chamber with an appropriate buildup cap. The configuration of such a measurement is shown in Figure 10.23.

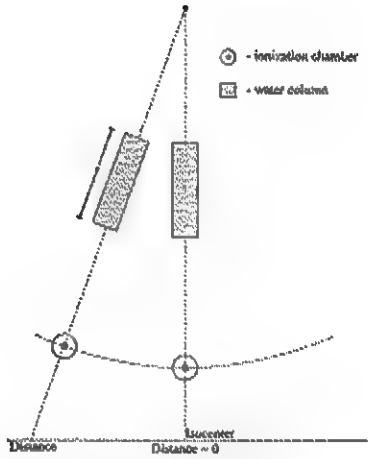


Figure 10.23 - Off-Axis Energy Measurement

The thickness (t) is varied until a 50% reduction in signal is seen. Published values of off-axis HVL have been measured in this way and reported in the literature for several accelerators. Note that for a cobalt unit, no appreciable variation in spectrum is expected across a field.

Though a description of the measurement is useful for understanding the data, it is a somewhat difficult measurement to make. Thus, it generally is more practical to infer the values from more customary measurements. The description which follows is of a technique to do so.

Collect and load all beam data necessary to do an external beam calculation. Include in the OCR data a set of scans which go across the diagonal of the largest square field size. Temporarily, include this set of profiles in the machine data and label it as 1.414 (i.e., $\sqrt{2}$) times the largest field size. Delete this data before clinical use so that this field size will not be available for patient planning.

Enter a rectangular water phantom as shown in Figure 10.24 and place an SSD beam whose collimator field size is that of the diagonal scans and whose effective field size is zero or very nearly zero. The effect of this is to approximate a beam with no scatter such that the isodose distribution is impacted only by absorption and inverse square losses. This is the arrangement needed for off-axis HVL determination.

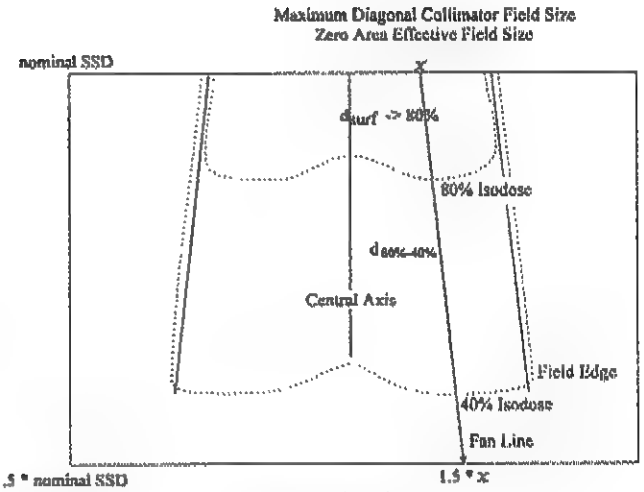


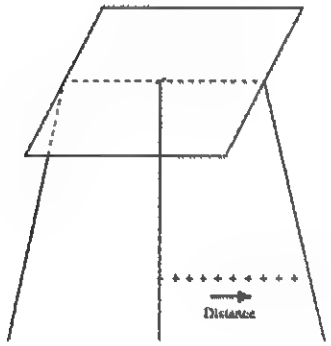
Figure 10.24 - Off-Axis HVL Determination

Calculate the dose distribution and generate two isodose lines whose values differ by a factor of two The 80% and 40% should work well. Construct a set of ray lines using geometric divergence from the front of the phantom to the back. Note where each ray line intersects the 80% and 40% lines. The distance between these two intersectors was required to reduce the beam by 50% and when corrected for inverse square along the fan line will be the HVL.

$$HVL = d_{80\%-40\%} * \frac{ln(2)}{-ln\left[\frac{1}{2} * \left(\frac{\sqrt{x^2 + (SSD_{NOM})^2} + d_{surf-80\%} + d_{80\%-40\%}}{\sqrt{x^2 + (SSD_{NOM})^2} + d_{SURF-80\%}}\right)^2\right]}$$

After calculating using this technique, the off-axis HVLs are required from the central axis to the corner of the largest square field size. If OCRs were available only up to the largest lateral field width, some extrapolation will be required.

After the off-axis HVLs are entered, they should be used by the irregular field program to try to predict measured OCR. Profiles for clinically important square field sizes and depths. Figure 10.25 shows the geometry of such a calculation as well as calculated profiles which could indicate a need to adjust the off-axis HVL values.



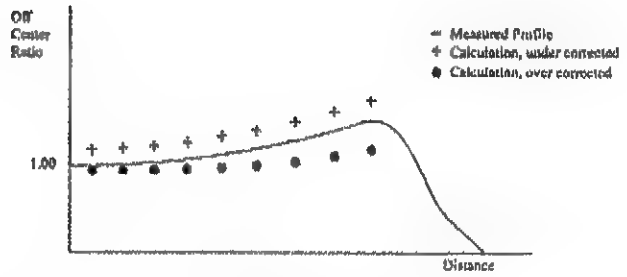


Figure 10.25 - Off-Axis Energy Verification

At least two entries are needed in the table shown in Figure 10.26. Four to five entries are generally sufficient. The numbers can be relative as they are used as a ratio for correcting the zero area TMR. The distance must start at the central axis (zero distance) and proceed in increasing distance along the diagonal to the corner of the field.

To enter the data, press Insert to create the number of entries you are going to enter, then enter the distance and the HVL at each distance point. After completing entry, save the data and Print.

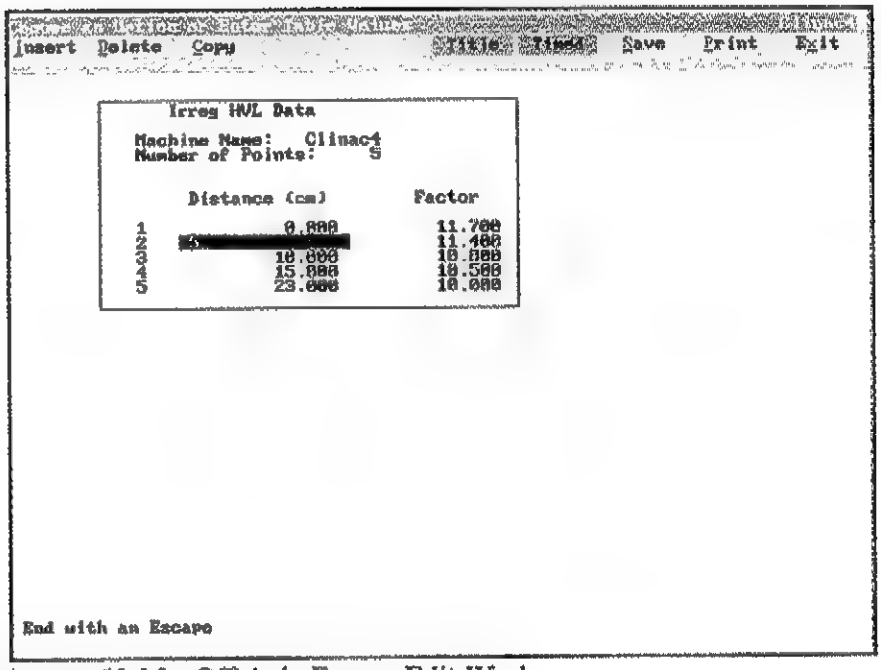


Figure 10.26 - Off-Axis Energy Edit Window

Technique #1: Measure the off-axis energy variation of HVL in water for primary beam at various distances off the central ray on the diagonal of an open field. This data is measured using a narrow photon beam collimated with lead bricks directed into a narrow column of water (graduated cylinder) positioned on a ray line off-axis. The data is an effective zero area HVL (or TMR at 50%).

Technique #2: Collect and load all physics data needed to make an external beam calculation. Digitize a patient contour which mimics the phantom in which the beam data was collected (i.e., a semi-infinite slab water phantom). Set up a treatment plan which mimics the scanning of the largest open field (e.g., 40x40, 80 or 100 SSD, no blocks, no wedge). Change the effective field size to a very small value (e.g., 0.5x0.5). This will remove all the scatter contribution from the dose calculation and the dose distribution will be as if geometric divergence and simple attenuation were the only relevant processes (i.e., you simulate "good geometry").

Next, display two isodose lines which differ by a factor of 2. The 80% and 40% should work well. Plot the plan at full scale. Choose points on the beam to find the HVL (e.g., 0, 5, 10, 15 cm) and draw fanlines from those points which diverge with the divergence of the beam.

Along each fanline, measure or calculate the distance from the source to the beam surface (SSD=100), the 80%ISO crossing, and the 40%ISO crossing. The distance from 80%ISO to 40%ISO (x) would be the HVL except for inverse square. Calculate the inverse square from 40%ISO to 80%ISO. It will be a number greater than one.

The next step is to back out the inverse square effect so that only attenuation remains.

$$HVL = \frac{x \ln(2)}{-\ln(0.5 * INVSQ)}$$

For either technique, the last and most crucial step is to enter the HVL data and try to reproduce the OCR table from an irregular field calculation. Minor adjustments may be required after this step. Ensure that data is entered to distances as great as the distance from the central axis to a beam corner. Extrapolation may be necessary.

PEAK SCATTER FACTOR ENTRY

A clinical x-ray beam's peak scatter factor (PSF) or back scatter factor (BSF) is the proportion by which the beam's apparent output is increased by back scatter from a phantom. PSF is measured as a function of square field size using the measurement setup depicted in Figure 10.27.

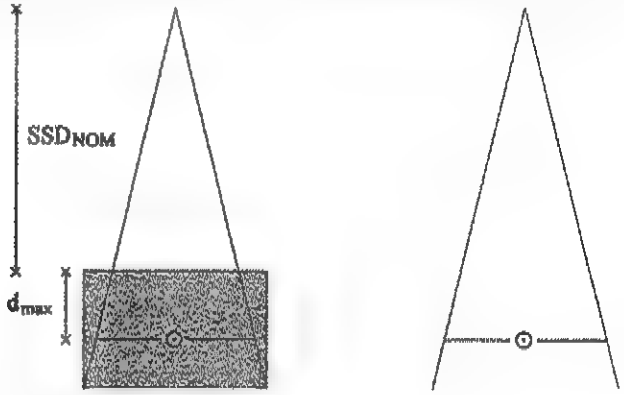


Figure 10.27 - PSF Measurement

An ionization chamber is setup in phantom at d_{max} and the machine's nominal SSD. Relative ionization is measured as a function of square field size. Then the process is repeated with the ionization chamber at the same location without a back scattering phantom, but only a build

up cap. The ionization values are ratioed to yield PSF as a function of field size on the surface.

PSF always takes on values which are no less than one and should monotonically increase with increasing field size.

Enter the values by selecting PS**F** which brings up the menu shown below.

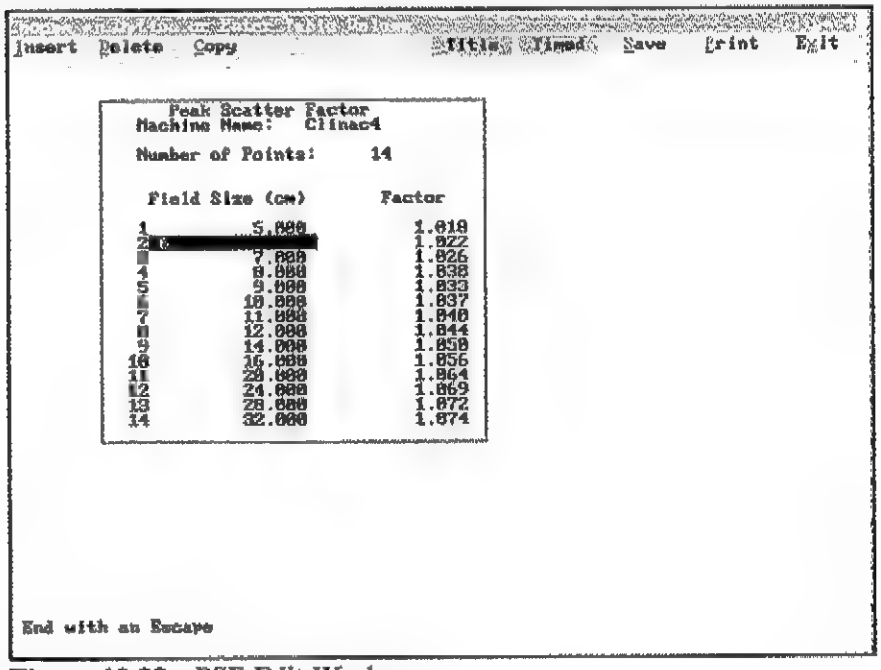


Figure 10.28 - PSF Edit Window

Enter the values for at least 3 and not more than 20 field sizes. The values must be entered in increasing field size. The value must be entered in increasing distances from the central axis. PSF data must be entered for field sizes up to the maximum collimator setting and is generally monotonically increasing.

VIRTUAL SSD

A clinical electron beam does not undergo simple geometric divergence and, thus, does not strictly conform to an inverse square low relationship. However, if the beam is treated as if it originates at a virtual source, an inverse square relationship is followed over a limited range of distances.

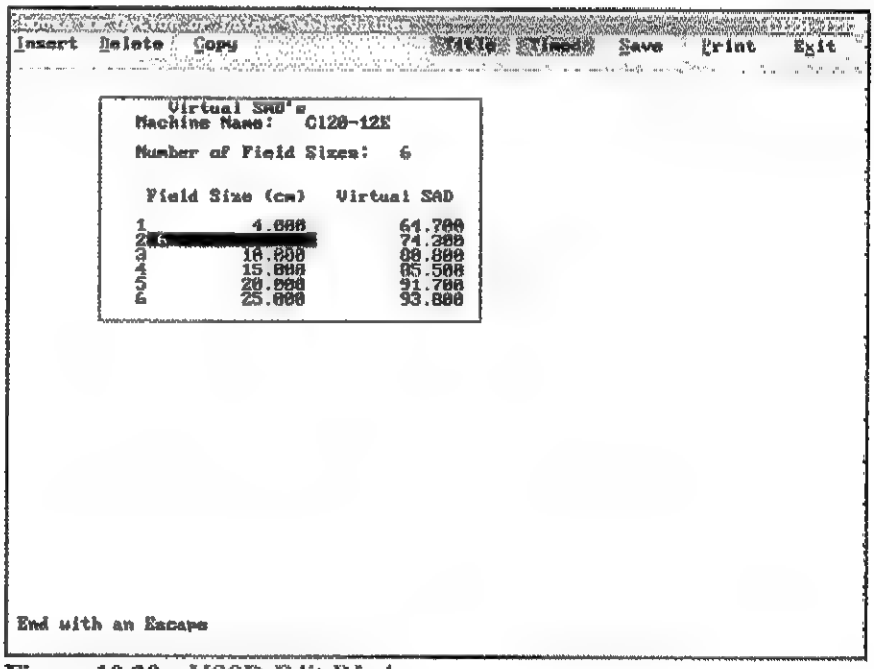


Figure 10.29 - VSSD Edit Window

Prowess calculations do consider this virtual source effect and the virtual source positions must be measured for each electron beam. Since the virtual source position can change with field size, it should be measured for all available electron cones or over the field sizes available.

The technique to be described for measurement of virtual SSD is that described and recommended by Khan. Make a series of relative dose measurements (Ig) along the central axis of the beam with differing gaps (g) between the cone end and phantom surface. Make measurements which cover the range from zero gap (Io) up to a 10-15 cm gap. See Figure 10.30.

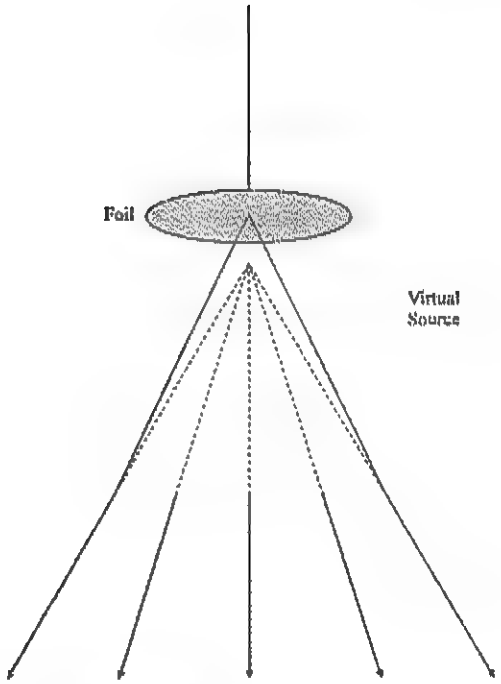


Figure 10.30 - Virtual Electron Source

Plot √Io/Ig against g and fit a line to the transformed data. See Figure 10.31.

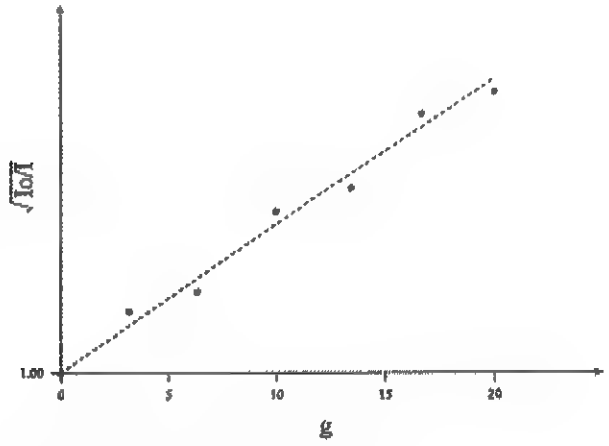


Figure 10.31 - Virtual SSD Data Analysis

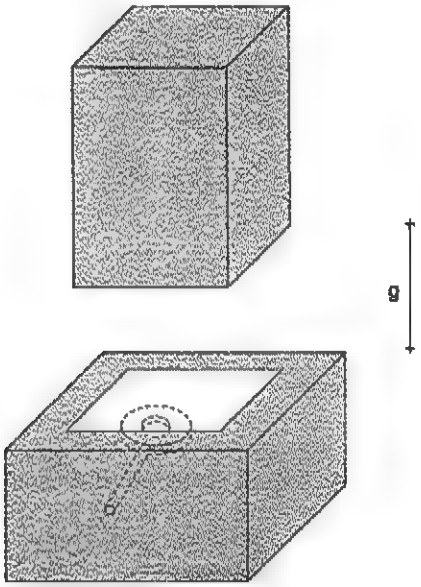


Figure 10.32 - Virtual SSD Measurement

Measure the slope of the line and calculation the virtual SSD as:

$$vSSD = \frac{1}{slope} - d_{max}$$

To enter the vSSD values, select ElecVir from the main machine data entry window. The vSSD edit window is shown in Figure 10.29. Use Insert, Delete, and Copy to create a vSSD table. Use the keyboard to enter the values. Select Print to print the table and Save and Exit when table entry is complete.

Note that vSSD values must be entered before converting %DD data to TMRs.

BLOCK EDGE TRANSMISSION

Block edge transmission edge data is stored by the type of block or edge. Type zero is reserved for the collimator. Numbers greater than zero can be used for any other block type used such as non-diverging lead, diverging cerrobend, and patient edge. Partial transmission blocks may be entered. Enter a descriptive title for each block type.

The data is stored as an array of transmission factors which depend on distance from the block edge. Distance into the beam is positive and

under the block is negative. All distances are in centimeters. Be sure the first and last points are far from the edge (±60). Transmission is defined as the blocked beam/open beam. It has a value of 1.00 when there is no edge effect and 0.00 when there is no transmission through the block. Distance is specified at isocenter and has a value of zero at the geometric edge of the beam. The first distance is outside the beam (negative distance) with increasing distances to follow.

Block edge transmission factors are measured by making two lateral scans: One with a block in place and one with no block as shown Figure 10.33. The results of these two scans are divided point by point.

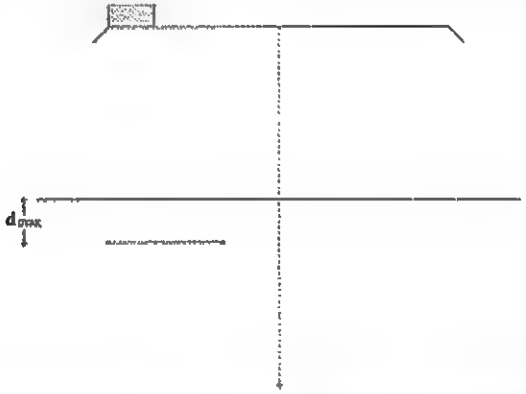


Figure 10.33 - Double Scan Geometry for Block Profile Determination

The raw values may need to be adjusted manually.

The shape and features of the edge factor profile is shown in Figure 10.34.

Diverging blocks are expected to have a sharper step through non-diverging blocks. The patient surface (flash) is entered as an ideal step function. This is shown in Figure 10.35.

Transmission blocks may be specified by causing the asymtotic tail of the transmission curve to be equal to the block transmission as shown Figure 10.36.

To enter edge characteristics select **Edge**. A list of edge types appear as shown in Figure 10.37.

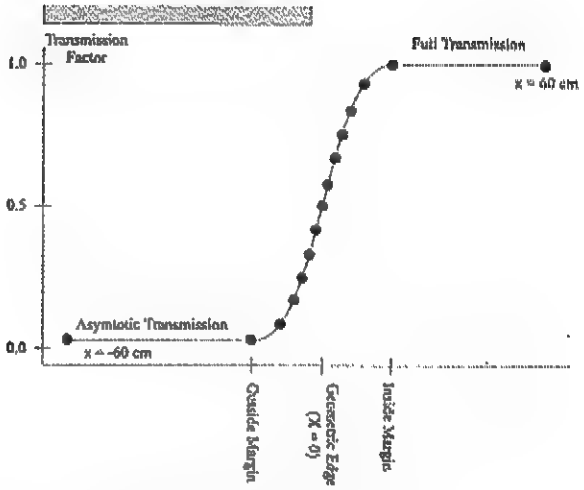


Figure 10.34 - Block Edge Profile and Features

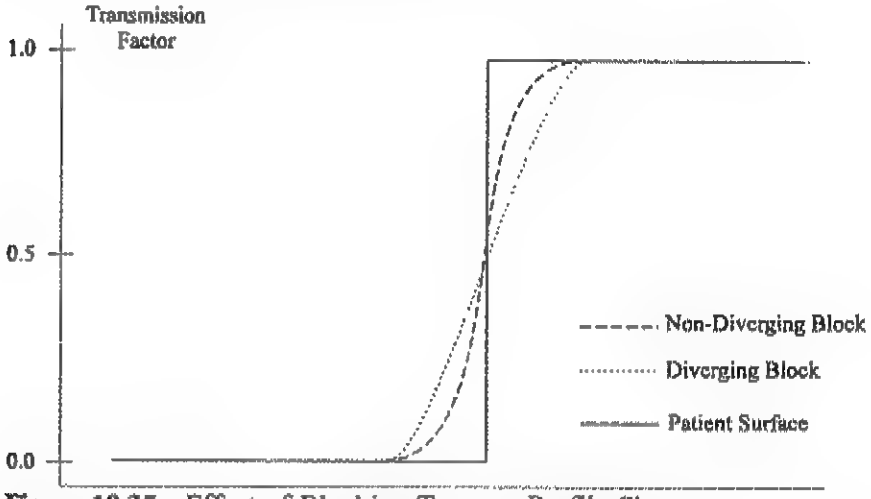


Figure 10.35 - Effect of Blocking Type on Profile Shape

To enter edge characteristics select Edge. A list of edge types appear as shown in Figure 10.37.

Add, delete, or choose one of these types. If one of the types is chosen or a new one is added, then a new menu appears as shown below with the distances and transmission factors as shown on the screen.

After selecting an edge type, the edge edit window is presented as shown in Figure 10.38.

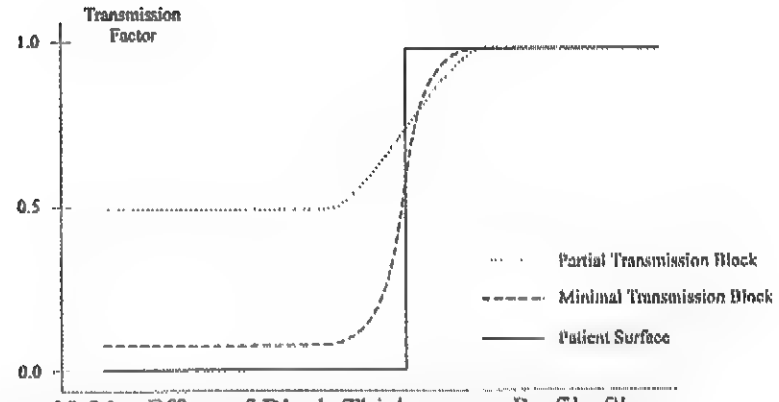


Figure 10.36 - Effect of Block Thickness on Profile Shape

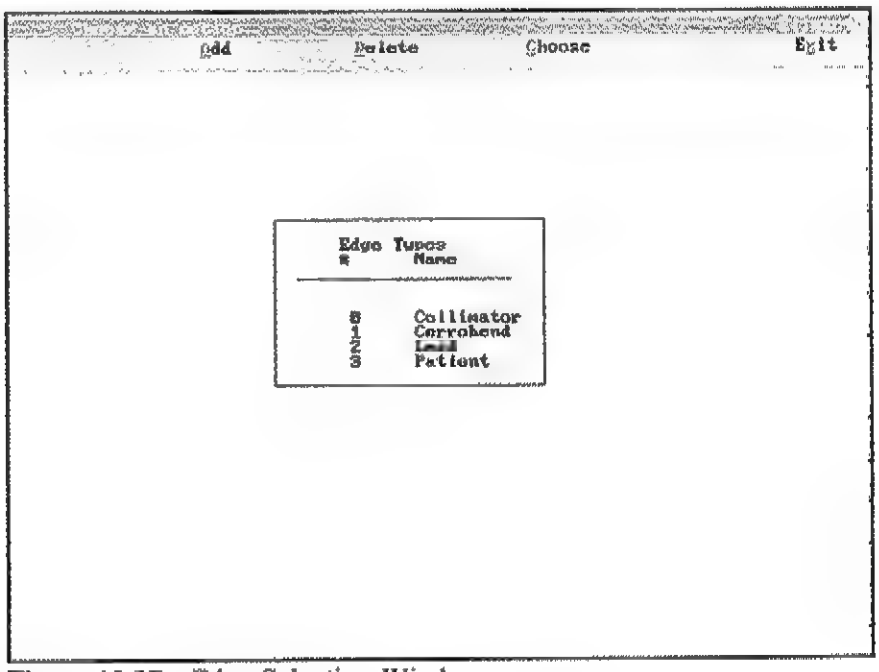


Figure 10.37 - Edge Selection Window

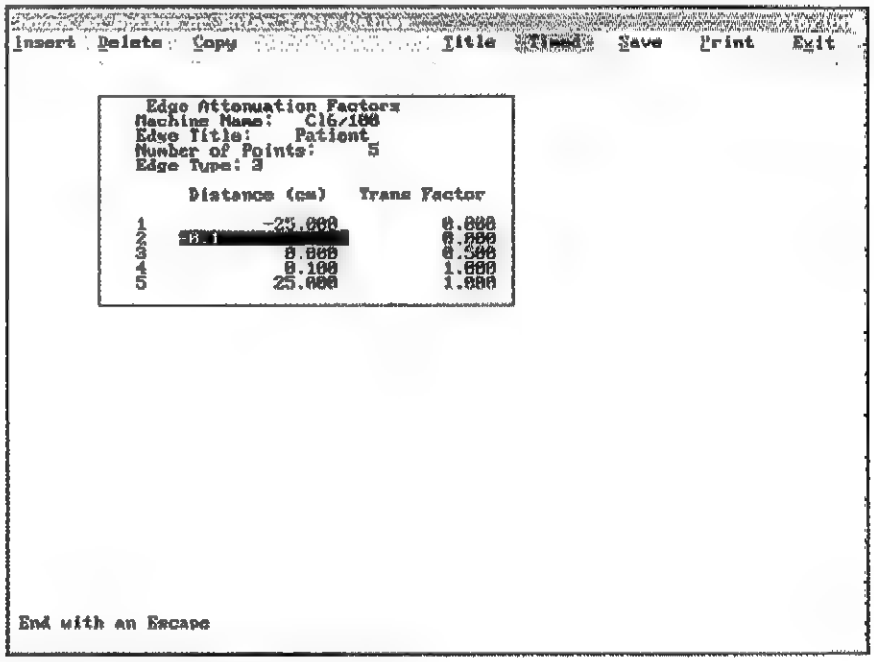


Figure 10.38 - Edge Edit Window

The title is entered by selecting Title. When finished, choose Save to save the values of ESCape to exit without change.

Before entering the edge types, decide what block types will be entered. If there is more than one machine in the department, you should enter them in the same order for all the machines so if machines are changed, the block types will match from one machine to the next.

To enter the first edge type, select Edge and then Add. Use Insert to insert the number of entries to be used for the block edge shape. Up to 25 entries for each edge type may be used and they do not have to be equally spaced. Start with the negative distances in the blocked edge of the field and proceed into the open beam. Typically, the block transmission factor will be a value near 0.0 under the block proceeding to 1.0 in the open beam. Enter the title. Save the data and print it. Enter all of the other block edge types in a similar manner.

The last edge entry should be the PATIENT edge type. This block type is used in the irregular field program when the beam flashes over the edge of the patient. There is no degradation in the beam shape due to

blocks. There is just a loss of scatter because no patient is present. This edge type should be a step function.

To obtain the edge data, take two scans with a field of 20-25 cm wide. One scan is an open field. The other scan is done with the block in the field. Mark the geometric edge on the scan. The block should be placed in the beam to fully block the beam from the starting of the block edge to the collimator edge of the field. It should also be arranged such that it minimizes the loss of scatter in the beam.

MACHINE DATA ENTRY USER INTERFACE

The machine data entry user interface is structured as shown in Figure 10.39.

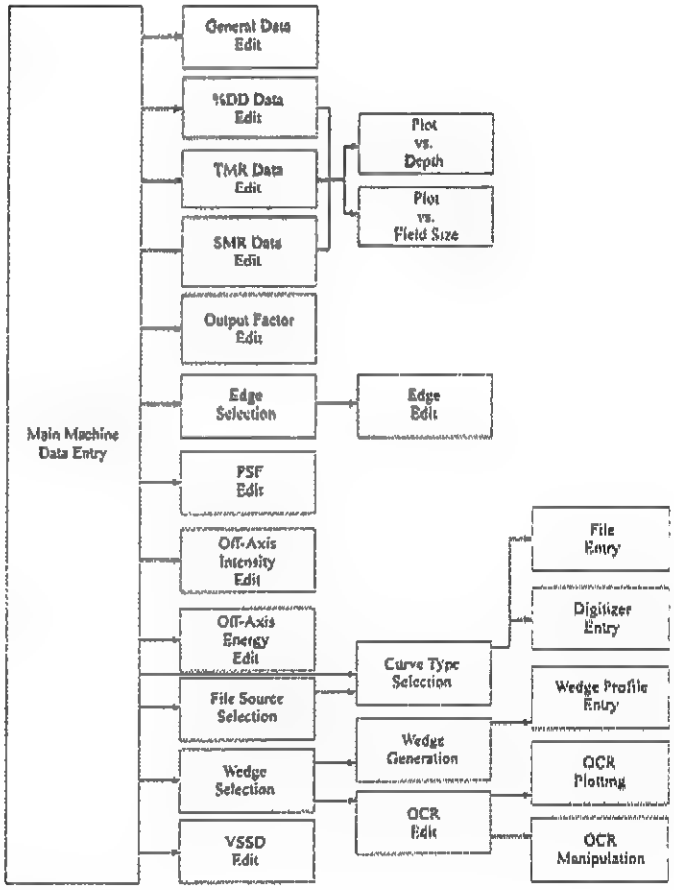


Figure 10.39 - Machine Data Entry User Interface

The function of the buttons presented in each of these windows is as follows:

Main Machine Data Entry Window

General - allows entry of general machine parameters.
TMR - allows entry/editing of TMR data.
SMR - allows entry/editing of SMR data.
Output - allows entry/editing of output factors.
Edge - allows entry/editing of edge transmission factors.
IregPro - allows entry/editing of irregular field profile data.
OCRPro - allows entry/editing of OCR profiles.
ElecVir - allows entry/editing of electron virtual SSDs.
DD - allows entry/editing of %DD data.
IregHVL - allows entry/editing of irregular field half value layers.
PSF - allows entry of ASCII text files.
Machine - allows selection of another treatment machine.
Digitiz - allows digitization of plotted curves.
Print - prints hardcopy of entire machine file.
Quit - quits without saving changes.

General Data Edit Window

Print - prints general data.
Accept - accepts general data.

%DD Data Edit Window

Insert - inserts a depth row.
Delete - deletes a depth row.
Copy - copies the current row to a new one.
C Ins 1 - inserts a field size column.
C Del 2 - deletes a field size column.
C Cop 3 - copies the current column to a new one.
Plot-Dp - plots %DD as a function of depth.
MakeTMR - calculates TMRs from %DD table.
Save - saves data to hard disk.
Quit - quits without saving changes.

TMR Data Edit Window

Insert - inserts a depth row.
Delete - deletes a depth row.
Copy - copies the current row to a new one.
C Ins 1 - inserts a field size column.
C Del 2 - deletes a field size column.
C Cop 3 - copies the current column to a new one.
Plot-Dp - plots TMR as a function of depth.
Plot-FS - plots TMR as a function of field size.
Extrapit - extrapolates data to greater depth.
MakeDD - calculates %DD table from TMR data.
MakeSMR - calculates SMR table from TMR data.

ZeroTMR - extrapolates TMR data to zero field size.
Save - saves data to hard disk.
Quit - quits without saving changes.

SMR Data Edit Window

Insert - inserts a depth row.
Delete - deletes a depth row.
Copy - copies the current row to a new one.
C Ins 1 - inserts a field size column.
C Del 2 - deletes a field size column.
C Cop 3 - copies the current column to a new one.
Plot-Dp - plots SMR as a function of depth.
Plot-FS - plots SMR as a function of field size.
Print - prints a hardcopy of SMR data.
Save - saves data to hard disk.
Quit - quits without saving changes.

Plot vs. Depth Window

PryMenu - returns to the previous menu.

Plot vs. Field Size Window

PryMenu - returns to the previous menu.

Output Factor Edit Window

Insert - inserts an entry.
Delete - deletes an entry.
Copy - copies an existing entry to a new entry.
Timed - specifies timer error and machine output.
Save - saves entered data.
Print - prints entered data.
Quit - quits without saving changes.

Edge Factor Selection Window

Add - add a new edge type.
Delete - delete an edge type.
Choose - choose to edit an edge type.

Edge Edit Window

Insert - inserts an entry.
Delete - deletes an entry.
Copy - copies an existing entry to a new entry.
Title - allows entry of an edge name.
Save - saves entered data.
Print - prints entered data.
Quit - quits without saving changes.

PSF Edit Window

Insert - inserts an entry.
Delete - deletes an entry.
Copy - copies an existing entry to a new entry.
Save - saves entered data.
Print - prints entered data.
Quit - quits without saving changes.

Off-Axis Intensity Edit Window

Insert - inserts an entry.
Delete - deletes an entry.
Copy - copies an existing entry to a new entry.
Save - saves entered data.
Print - prints entered data.
Quit - quits without saving changes.

Off-Axis Energy Edit Window

Insert - inserts an entry.
Delete - deletes an entry.
Copy - copies an existing entry to a new entry.
Save - saves entered data.
Print - prints entered data.
Quit - quits without saving changes.

File Source Selection Window

CMS - reads OCR data from the CMS-PC scanning system.
Welhof - reads OCR data from the Welhofer scanning system.
CRS - reads OCR data from the CRS scanning system. Profiles are read in one depth at a time.
MultiDt - reads OCR data from the MultiData scanning system.
MultiPln - reads all OCR wedge files directly into the appropriate wedge number.
MRxPln - reads full data sets from a text file generated by the MARx Plan treatment planning system. This file is generated by diverting the MARx Plan machine data file print option to a text file on the hard disk of the computer. This option converts the MARx Plan data to PROWESS data format.
Accuscan - reads OCR data from the Accuscan scanning system.
PTW - reads OCR data from the PTW scanning system. This is the old version of the scanner software developed in New York.
SCANDTX - reads OCR data from Scanditronix scanning system.
WritTxt - copies all the machine data stored in the active machine file to an ASCII text file.
ReadTxt - reads the ASCII text file generated by WritTxt. Note that you may edit files after writing and before reading them.
Machine - selects a new machine for processing data.

Curve Type Selection Window

TMR - enter TMR curves.
%DD - enter %DD curves.
OCR - enter OCR curves.
Exit - exit data entry.

File Entry Window

Add - adds a new profile to the table.
New clears the active table to permit entry of data for a new field size.
MakeTbl - saves the table to the appropriate field size.
Smooth - smooths the data.
RePlot - replots the data.
Quit - quits without saving changes.

Digitizer Entry Window

Add - adds a new profile to the table.
New clears the active table to permit entry of data for a new field size.
MakeTbl - saves the table to the appropriate field size.
Smooth - smooths the data.
RePlot - replots the data.
Quit - quits without saving changes.

Wedge Selection Window

Copy - copies a wedge.
Add - adds a wedge.
Delete - deletes a wedge.
Choose - chooses a wedge for editing.
GenWedg - generates a wedge from open field data.
Quit - quits without saving changes.

Wedge Generation Window

CngType - changes wedge type calculated.
Profile - allows entry of wedge profile.
Print - prints wedge generation parameters.
Save - saves wedge generation parameters.
Exit - exit wedge generation.

Wedge Profile Entry Window

Insert - inserts a table entry.
Delete - deletes a table entry.
Copy - copies a table entry.
Save - saves the wedge profile.
Print - prints the wedge profile.
Exit - exit profile entry.

OCR Edit Window

Insert - inserts a distance row.
Delete - deletes a distance row.
Copy - copies the current row to a new one.
C Ins 1 - inserts a field size column.
C Del 2 - deletes a field size column.
C Cop 3 - copies the current column to a new one.
Plot - plots the OCR profiles on the screen and optionally on a plotter.
Save - saves data to hard disk.
Quit - quits without saving changes.
DelFS - deletes the active field size.
EdtName - allows editing of the profile name.
FanSpac - allows editing of the fanline spacing (not used in calculations).
WedgFac - allows entry of the wedge factor for the current field width.
Type - allows entry of the wedge type for screen display:
- 0 = open
- 1 = normal wedge
- 2 = beam splitter
- 3 = beam split wedge

FScopy - copies the active field size into a new field size.

OCR Plotting Window

Hardcpy - plots the OCR curves on paper.
Print - prints the OCR data on paper.
IncrFS - increments to the next field size.
DecrFS - decrements to the previous field size.
PryMenu - returns to the previous menu.

OCR Manipulation Window

Invert - inverts the OCR profile and reverses the orientation of the wedge.
Normalz - renormalizes OCR curves to a value entered.
CpyLft - copies the left half of the profile to the right.
CpyRt - copies the right half of the profile to the left.
Avg - averages the left and right side of the profile.
Trnfrm - This adds or subtracts (depending upon sign) a value to/from the profile.

VSSD Edit Window

Insert - inserts an entry.
Delete - deletes an entry.
Copy - copies an existing entry to a new entry.
Save - saves entered data.
Print - prints entered data.
Quit - quits without saving changes.

CALCULATION ALGORITHMS

EXTERNAL BEAM

The External Beam Calculation module is used to calculate the two-dimensional dose distributions across multiple slices of a teletherapy patient. As many as 40 beams may be included in a single plan. Each of these beams can be fixed SSD, fixed SAD, or rotating from any machine for which data has been entered. Doses are calculated at grid points equally spaced across the calculation area. The matrix size can be varied from 100 to 16,384 points with a default of 1024. After calculation, the dose matrix is stored for rapid display of the isodose pattern and easy renormalization without recalculation.

Wedges, blocks, compensators, and bolus can be added to any photon beam. Blocks and bolus can be added to any electron field. A wedge is added by selecting one of the wedge types stored in the data file. Blocks can be entered by specifying their shape and type from Beam's Eye View. The block type is chosen from one of those listed in the machine file. A compensator is entered by specifying the compensator thickness along the central axis. To specify no compensator, enter a thickness of 0.00 cm. To specify a compensator present with infinitesimal central axis thickness, enter a thickness of 0.01 cm. Bolus is entered by specifying the bolus thickness.

To simplify treatment planning, defaults are provided for all required parameters. These values are located in the program control file and can be changed by editing this file.

Contours can be entered manually using a digitizer or mouse or automatically using CT autocontour. The crucial element of a patient slice is the external contour which is assumed to enclose unit density tissue. This contour must be entered before any external beam calculation can be made. The density of structures defined by internal contours can be specified.

Contours are entered as a sequence of one or more end points. Each pair of end points is linked by a straight line segment. These

points may be spaced no less than 0.5 cm apart. In addition to the external contour, PROWESS contour types include reference points, calculation points, structures, heterogeneities, and tumors. A reference point is a single point entered only to indicate a location. A calculation point differs from a reference point in that its dose is calculated and reported. A structure is a sequence of connected reference points which need not be closed. A heterogeneity differs from a structure in that it must be a closed structure and the density of the enclosed region may be specified. A tumor differs from a heterogenity in that dose statistics (minimum, maximum, and mean) are calculated for the region enclosed.

Photon Beam Model

The photon beam model used to calculate the dose distribution inside a patient is an expanded and improved version of the two-dimensional model developed at Memorial Hospital[1]. Three different heterogeneity models are available. These are the Effective Path Length[1&2], Batho Power Law[10], and Equivalent TMR correction[11]. Each of these models are discussed below.

Figure 11.1 describes the calculation geometry.

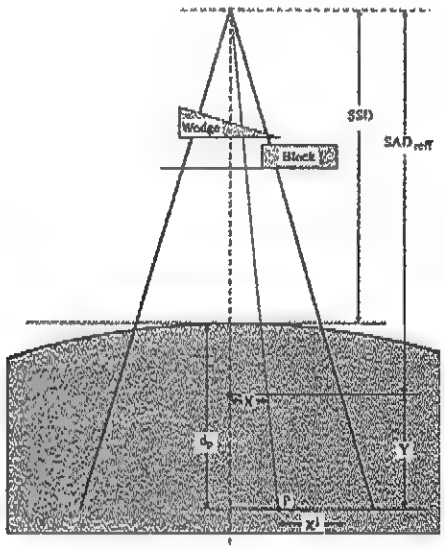


Figure 11.1 - External Beam Calculation Geometry

This is an isocentric beam which passes through an off-axis heterogenity. The beam has a collimator field size of FS and a blocked field size of FS'. Both of these field sizes are referenced to the machine isocenter. Point P is the point to which the dose is calculated. Point P is located at depth d_p and a distance X_d from the central axis. The dose to point P, D(P) is calculated as described below:

D(P) = Beam Weight *
Machine Output *
Collimator Output Factor *
Peak Scatter Factor Correction *
Inverse Square Calculation *
Tissue Maximum Ratio *
Off-Center Ratio *
Heterogeneity Correction *
Block Edge Factor *
Modifier Transmission Factor

Where:

Beam Weight = Machine setting, monitor units, or treatment time.

Machine Output = Calibrated dose rate * Cobalt decay factor.

Collimator Output Factor = 0(FS)

FS = Collimator field size as projected to isocenter.

Peak Scatter Factor Correction = PSF(FS') / PSF (FS).

FS' = Blocked field size as projected to isocenter.

Inverse Square Correction =

SAD_{eff} = Nominal source to axis distance.

d_{max} = depth of dose maximum.

Y = Distance from isocenter to point P along the central axis.

Tissue Maximum Ratio = TMR(FS'_d, d_p)

FS'd = Blocked field size as projected to d_p.

d_p = Calculation point depth projected to the central axis.

Off-Center Ratio=

$\frac{2X}{FS}$ = Relative distance of point P from the central axis to the beam edge.

FS = Collimator field size as projected to isocenter.

d_p = Calculation point depth projected to the central axis.

Wdg = Wedge

Heterogeneity = Correction factor determined using Correction heterogeneity model.

Block Edge Factor = Bf(x')

X' = Distance from point P to block edge projected to d_p.

d_p = Calculation point depth projected to the central axis.

Modifier Transmission Factor= Wf * Tf * Cf

Wf = Wedge transmission factor.
Tf = Tray transmission factor.
Cf= Compensator transmission factor.

The following sections elaborate on the components of this calculation.

Field Size (FS): The field size is specified at SAD_{reff} by two sets of parameters: Collimator settings and the effective field size. The collimator field size (FS) is based on the collimator setting. The effective field size (FS') is the blocked field size as seen by the patient. Both collimator and effective field dimensions are converted to an equivalent square before use in calculations.

$$Equivalent\ Square = \left[\frac{2xy}{x + y}\right]$$

Depth of Dose Maximum (d_{max}): The depth of dose maximum is specified along the central axis of a 10 x 10 cm field at nominal SSD.

TMR: The Tissue Maximum Ratio[7,12] is defined as the ratio of the dose at a point when that point lies under a depth d of tissue to the dose when that point lies under a depth d_{max} of tissue.

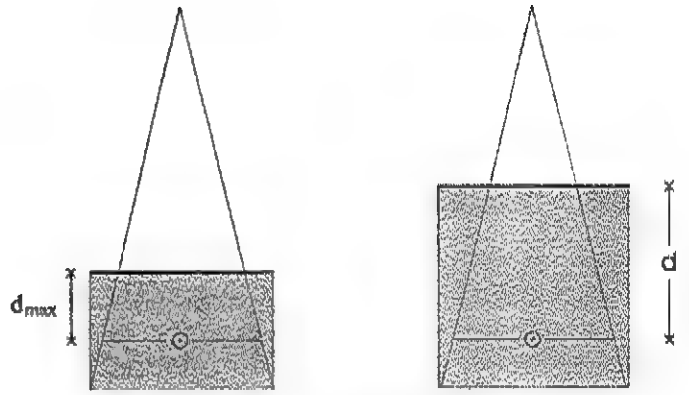


Figure 11.2 - Tissue Maximum Ratio Geometry

It is related to the central axis depth dose at nominal SSD by the following equation:

$$TMR\ (d,\ FS') = \frac{\%DD\ [d,\ (FS * \frac{SSD + d_{max}}{SSD + d}),\ SSD]}{100} * \left(\frac{SSD + d}{SSD + d_{max}}\right)^2 * \frac{PSF(FS)}{PSF(FS')}$$

During machine data entry, the peak scatter ratio correction is neglected. The error introduced is small. The TMR table looks up the %DD value for the field size defined at depth. For small field sizes this presents a problem because a 3 cm %DD curve does not give adequate data for a 3 cm TMR table. TMR data for a 3 x 3 cm field can be measured directly or calculated from 2 x 2 cm data.

Off Center Ratio (OCR): The OCR characterizes the shape of the dose distribution around the central axis of an open beam. The OCR values are stored in dimensionless units of 2X/W where W is the full geometric (50% to 50%) width of the beam (FS) and X the distance from the central axis. A 2X/W distance is the proportion of the distance from the central axis to the field edge. Profiles of various depths are stored to account for the profile change as depth increases. Generally, the OCR is normalized to 1.0 on the central axis at all depths. OCRs are used in all external beam calculations.

When calculating an off-axis slice, vertical and lateral displacements are considered separately and multipled.

$$OCR = OCR_{lateral} * OCR_{vertical}$$

No collimator rotation is possible for wedged fields. Figure 11.3 describes the geometry.

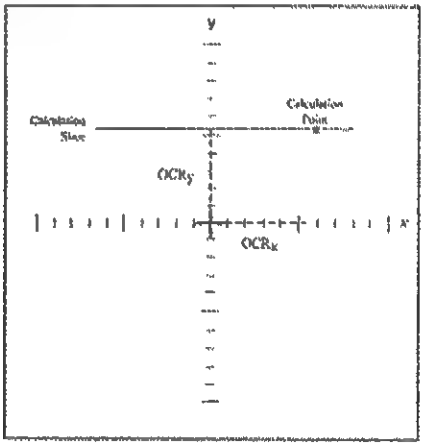


Figure 11.3 - OCR Geometry

Note: Because this is a 2-D calculational model, errors in calculations can occur near the edge of the field where radial symmetry does not describe the beam shape well.

The wedge factor can be built into the profile by normalizing the profile along the central axis to the wedge factor and setting the wedge factor to 1.0. This is not recommended since it is confusing. The profile can also be normalized to correct for wedge beam hardening. This is advised if the wedge hardens the beam significantly.

Weight (Wt): A beam's weight can be specified in one of two ways, either the machine setting or the dose to a weight point (isocenter, d_{max}, or a calculation point). If the machine setting is specified, then the treatment duration is already known and PROWESS returns the resulting doses. In the more typical case, the dose (or percent dose) and weight point is specified and PROWESS returns the monitor units required. It is important to

be very careful to what point the dose is specified. If the weight point has a dose which is small relative to the plan (e.g., on the central axis of a split field), then unacceptably large monitor units can be calculated resulting in unacceptably large doses elsewhere in the slice.

In the case of a dose point weighted beam, the calculation is a three part process. First the weight dose and weight point are used to calculate the machine sestting. Secondly, the relative dose (dose/monitor unit) is calculated to all points in the patient. Third, the monitor units and relative dose are multipled to yield the absolute dose at every point. For beams weighted to machine setting, the first part is not necessary.

Block Edge Correction: The block edge transmission correction modifies the shapes of a beam near a block edge. Its value depends only on the distance of a point from the block edge. The block edge transmission factor and TMR of the blocked field size are the two correction techniques used to reflect the effect of secondary blocking (or asymmetric collimation) on a beam. The block edge transmission correction diverges with the beam and partial transmission blocks are permitted.

Bolus Correction: Bolus may be added to any beam including one with a compensator. If bolus is added to a beam, then the contour is enlarged by the thickness of the bolus for that beam.

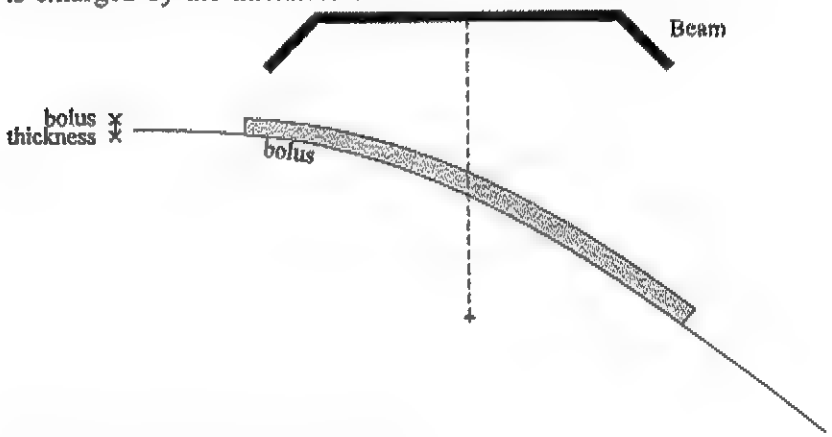


Figure 11.4 - Bolus Geometry

SSDs are specified to the patient surface ignoring bolus. Aside from increasing patient thicknesses, there is no difference in calculating the dose to the patient. When weighting a beam with bolus, the depth to weight points includes the bolus. When plotting isodose curves for beams with bolus, the curves will go outside the patient surface reflecting dose build up in the bolus. Partial bolus can be added to the patient surface using an external heterogeneity.

Compensator Correction: A compensator may be added to any beam including one for which bolus has been added. Adding a compensator to a beam fills the patient entrance surface for that beam, so that it is flat perpendicular to the central axis of the beam. The surface is filled to the thickness specified on the central axis. If part of the patient surface protrudes beyond the compensator, then the actual patient contour is used for calculation. An example of this would be a sloping chest wall where the compensator only extends to the central axis of an anterior field. The compensator would fill the cephalad part of the field, but use the patient's contour caudad of the central axis. To add a compensator with no thickness on the central axis, choose a thickness of 0.01 cm. A value of 0.00 means no compensator is present. When plotting isodose curves for beams with compensators, the curves do not extend outside the patient surface. This reflects the dose build up at the actual surface of the patient.

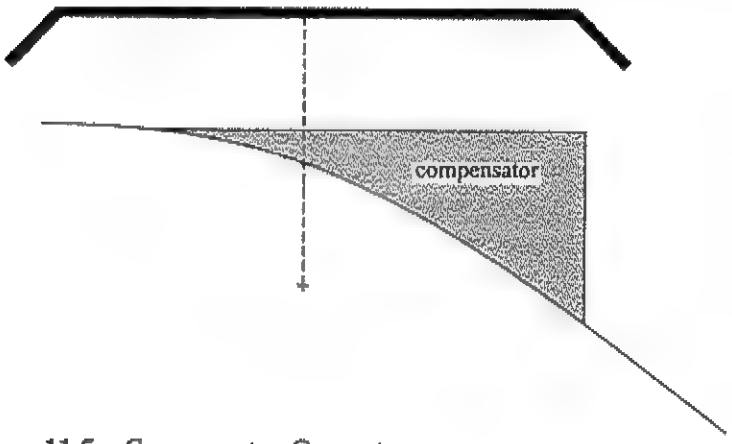


Figure 11.5 - Compensator Geometry

The preceding technique is used to determine how much tissue equivalent compensation lies over a calculation point. An effective transmission factor is determined for this thickness. This factor is determined by ascertaining the extent to which this additional material reduces the TMR at a distance of 8 cm below the calculation point. The 8 cm shift is introduced to ensure that all table loop ups are made in the exponential part of the TMR curve.

A compensator can be added to the patient surface by entering an external inhomogeneity. Clearly, skin sparing is not reflected using this technique. Where a bolus and a compensator are both specified, the bolus is included first such that compensation is to the surface of the bolus.

Heterogeneity Correction: Three options are available for corrections for patient surface curvature and inhomogeneities. These choices include the Effective Path Length model, the Batho Power Law model, and the Equivalent TMR model. Optionally, you can make no correction at all. The program defaults to correct for inhomogeneities, if present. All of these corrections are bulk corrections, not pixel by pixel. One must assign a density to a closed contour inside or outside the patient to make an inhomogeneity correction. Corrections for missing tissue are always made. Only one inhomogeneity model may be used at a time. The calculation model is selected by the physicist from the control file.

A good review of heterogeneity correction models is discussed by Wong & Purdy.[10] As they point out, the models which treat this problem best are too complex for most routine calculations.

All heterogeneity correction models generate a correction factor, I. The techniques for calculating I are given below.

Effective Path Length Model: The traditional correction for heterogeneities uses the density weighted effective path length. In this model, the correction becomes:

$$I = \frac{TMR(FS', \sum_{i=1}^{n} \rho_i d_i)}{TMR(FS', \sum_{i=1}^{n} d_i)}$$

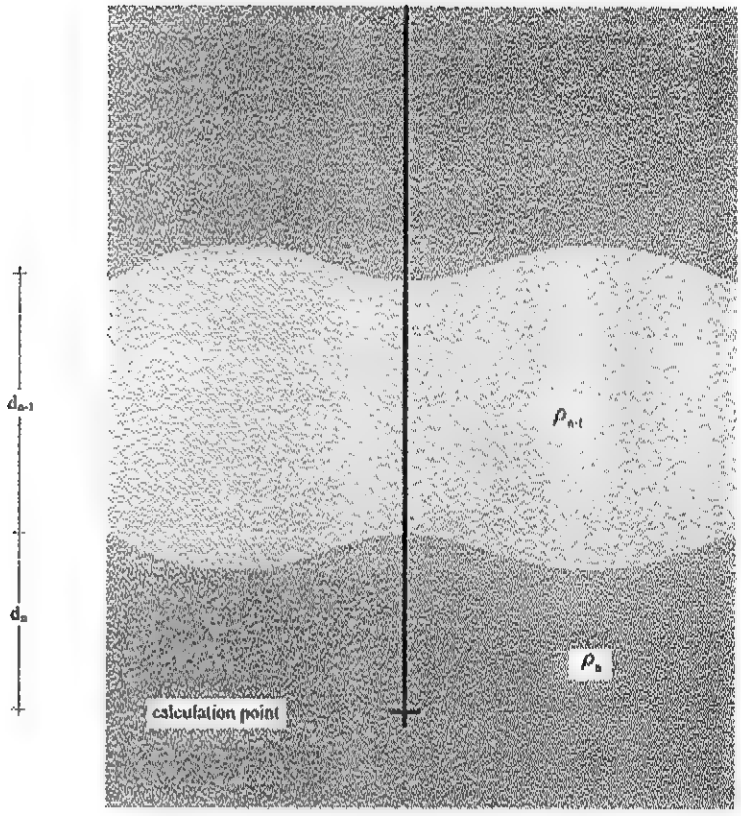


Figure 11.6 - Effective Path Length Geometry

Equivalent TMR Model: This model was introduced by Sontag & Cunningham[11]. It accounts for the change in scatter contribution from adjacent media. We chose to average over three fanlines spaced d_{max} apart. Therefore the inhomogeneity correction becomes:

$$I = \frac{1/3\sum_{j=1}^{3}[TMR(FS'_d, \sum_{i=1}^{n} \rho_{i,j}\, d_{i,j})]}{TMR(FS'_d, \sum_{i=1}^{n} d_i)}$$

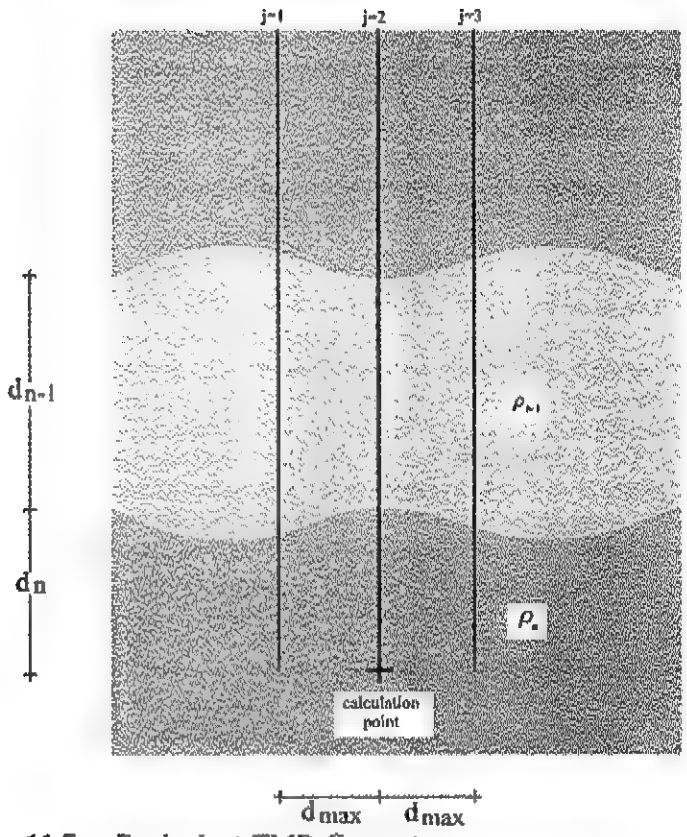


Figure 11.7 - Equivalent TMR Geometry

Batho Power Law Model: The model was originally presented by H. F. Batho in 1964.[8] Numerous authors have improved upon the original derivation. The form that we implemented is described by El-Khabb & Batista[9]. Remember, this correction is not valid in the build-up region of the inhomogeneity. As such, it is ignored in this implementation of the algorithm. The inhomogeneity correction becomes:

$$I = \frac{TMR(FS', Z_1)^{\rho_2}}{TMR(FS', Z_2)^{1-\rho_2}}$$

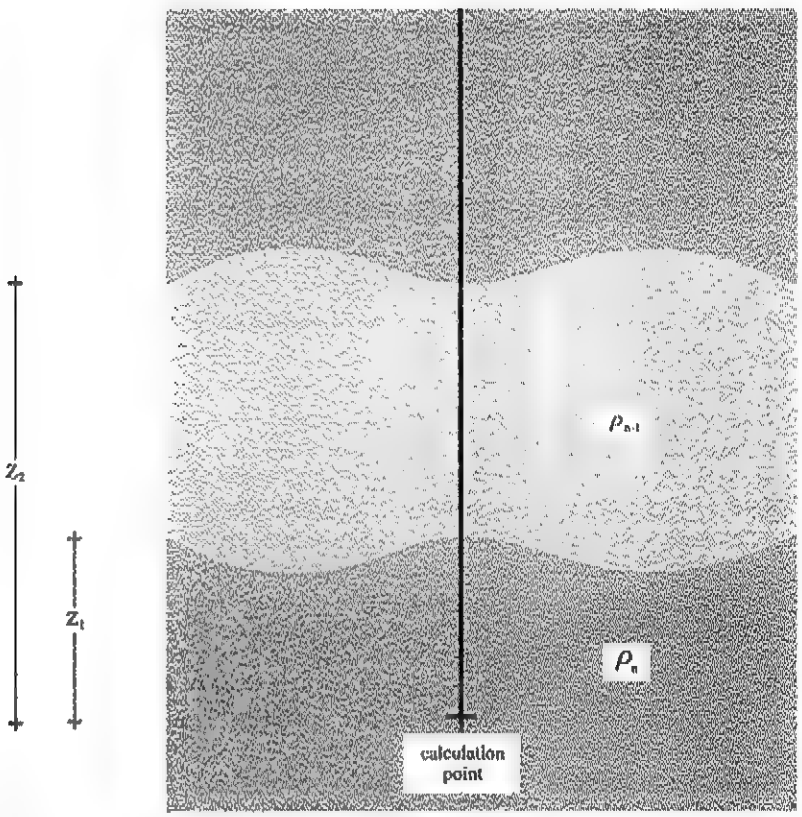


Figure 11.8 - Batho Power Law Geometry

Correction for Patient Curvature: Figure 11.1 shows the geometry used to calculate the dose to point P. Since the patient surface is not flat, the ray from the source to point P traverses an area of missing tissue. To correct for this, the ratio of TMR correction is used. This correction function is:

$$I = \frac{\text{TMR } (FS'_d, m)}{\text{TMR } (FS'_d, s)}$$

Where
s = slant depth from source to point P for a flat surface.
m = slant depth from source to point P for the curved surface.

The same calculation technique is used for an SSD beam. An SSD beam is considered to be an isocentric beam whose isocenter is located on the surface.

Arc Rotations: Arc rotation calculations are treated as the sum of multiple fixed beams applied uniformly over the range of the arc. Each beam is weighted equally. A minimum of six beams are used for the summation. The default angle increment is 10 degrees. This can be reset. No beam is added at the exact ends of the rotation as the beam spends no time at these angles.

Data Format & Look Up: Data used in this calculation is stored in vector or matrix format and interpolated when necessary. TMR tables contain as many as 20 field sizes and 50 depths. The off-center ratios for each wedge are stored in an array of up to 50 distances and 10 depths. One depth must include d_{max}.

For calculations requiring greater depth than those measured for the TMR table, an exponential fit to the data is assumed beyond the last depth. If the last measured depth is 40 cm, then this extrapolation will very seldom be necessary. The dose error associated with this assumption should not exceed 2%. This extrapolation must be done at the time the machine data is entered. No extrapolation is done in the external beam calculation.

TMR is assumed to vary linearly between stored values. To obtain reasonable accuracy, several TMR values should be included in the build up region. Like most treatment planning systems, the accuracy of dose calculations in this region is not very good and should be used with care.

For table lookup in off-center ratios which exceed the table's width, the profile is assumed to vary linearly with distance from the last value to zero at two times the width of the field size. This should create errors no greater than 3% in areas outside the primary beam. If the depth exceeds the table depth, the profile of the largest depth is assumed. No significant error is expected from the assumption as the profile shape varies slowly with depth.

Accuracy: The expected accuracy of the model is well within ±5% inside the beam for homogeneous media. When inhomogeneities are entered, the error will increase. Careful choice of the density of the inhomogeneity will minimize this error. No model depicts the dose accurately within the buildup region of an inhomogeneity. Errors as large as ±10% in this region can be expected.

Off-axis plane calculations assume radial symmetry. Therefore, the OCR is chosen by 2X/W that is the diagonal distance from the central axis to the calculation point. This assumption should create errors no greater than ±5% except near the edge of the beam. Errors in this region may exceed ±10% and such calculations should not be performed. In extreme cases, near the corner of rotated fields, the error can exceed ±20%. Therefore, use of off-axis calculations in these regions is not advised.

Electron Beam

Only one model is available to calculate the dose from electron beams at present. It is a simple model developed by Memorial Hospital[4].

$$D(P) = \frac{VSSD_{eff}}{VSSD_{eff} + y} * TMR(FS_d', d_p) * OCR(\frac{2x}{FS'}, d_p) * Wt * O(FS)$$

Where

VSSD = virtual source to skin distance for each electron cone and energy

d_p = *depth of point P*

FS' = *field size at point P*

x = *perpendicular distance from central axis to P*

$TMR(FS_d', d_p)$ = *Pseudo Tissue Maximum Ratio for electrons for field size* FS_d' *and depth* d_p

$OCR(\frac{2x}{FS'}, d_p)$ = *Off Center Ratio at distance* $\frac{2x}{FS'}$ *from central axis and depth* d_p

Wt = *The desired weight at* d_{max} *from the beam*

$O(FS)$ = *output factor for cone size specified at nominal SSD and a depth of dose maximum*

y = *depth on central axis to point P*

Pencil Beam Electron Model

The pencil beam calculation algorithm couples the technique of linear superposition with the results of the Fermi-Eyges transport equation in a slab geometry.[5] A clinical electron beam is made by

impinging an essentially monodirectional, monoenergetic, one-dimensional beam of megavoltage electrons on a broadening device (either a scanning magnet or, more commonly, a high-Z foil). The beam is then modeled as a set of discrete rays (pencil beams) which radially diverge from the surface of the foil. Each pencil beam is described by two parameters. The average electron energy (T) and the variance of the direction of travel (σ^2). As the beam exits the accelerator, all pencil rays are assumed to have energy (T_0) and direction variance ($\sigma_{\theta x}$).

The transport of radiation is modeled by two decoupled processes. Longitudinal penetration and lateral spread / energy deposition.

Penetration: Penetration affects both energy and direction variance.

Energy Degradation: As a pencil beam penetrates air (or more accurately, a vacuum) its energy is not degraded. As it penetrates a medium, the average energy is a decreasing function of penetration depth. This decrease is described by the Harder Linear Energy Relation. This relation is based on the continuous slowing down approximation (CSDA).

$$T(z') = T_0 \left[1 - \frac{Z_{eff}(z')}{R_p} \right]$$

A ray tracing approach is used and the effects of inhomogeneities are reflected by the effective radiological depth. In calculating the radiological depth, penetration distances are weighted by linear collisional stopping power.

$$Z_{eff} = \int_{-\infty}^{z} \frac{(dE/dZ')}{(dE/dZ')_{H_2O}} dZ'$$

Range straggling is neglected. In addition, a slab geometry is assumed. The effective depth of one pencil beam does not affect the energy of an adjacent one. Relative linear collisional stopping powers are based on CT numbers as described in Hogstrom, Table 1[5].

Direction Variance: As a pencil beam with an initial direction variance penetrates air, the variance increases due to geometric projection.

$$\sigma^2_{air} = (Z + L_0)^2 \, \sigma^2_{\theta_x}$$

As it penetrates inhomogeneous tissue, it also diffuses due to multiple Coulomb scattering (MCS). The magnitude of σ^2_{MCS} of a pencil beam which has penetrated inhomogeneous tissues is based on a form of radiological path length using linear angular scattering power.

$$\sigma^2_{MCS} = \frac{1}{2} \int_{L_0}^{z} (Z - Z') \frac{d\,\sigma^2_{MCS}}{dZ'} \, dZ'$$

To decrease the calculation time, Hogstrom's moment equations are used as a numerical approximation of this equation.

$$M_0^{ij} = M_0^{i-1,j} + \Delta Z \left[\frac{d\sigma^2_{MCS}}{dZ} \right]_{i-1,j}$$

$$M_1^{ij} = M_0^{i-1,j} - M_0^{i-1,j} - \Delta Z \left[\frac{d\sigma^2_{MCS}}{dZ} \right]_{i-1,j}$$

$$M_2^{ij} = M_1^{i-1,j} - 2M_1^{i-1,j} + M_0^{i-1,j} + \Delta Z \left[\frac{d\sigma^2_{MCS}}{dZ} \right]_{i-1,j}$$

These contributions are considered and calculated independently, then summed.

$$\sigma^2_{MCS} = \sigma^2 + \sigma^2_{air}$$

A simplified version of these moment equations is also used to calculate the direction variance distribution in a semi-infinite water phantom.

$$\sigma^2_{MCS}\,[M_2^{ij} + M_1^{ij} + \left[\frac{M_0^{ij}}{3}\right]\,]\,\Delta Z^2$$

Lateral Spread: To incorporate the effect of lateral spread and calculate a planar dose distribution involves a two-step process. First, the electron flux distribution is calculated neglecting the effect of multiple Coulomb scattering in tissue.

$$S_{air}(X'',Z) = \frac{1}{2\pi\ \sigma^2_{air}} \int_{-\infty}^{+\infty} S(x',\ y')e^{\frac{-(x'-x'')^2}{2\sigma^2_{air}}}\ dX'$$

Next, the effect of MCS is included.

$$D(X,\ Z) = \int_{-\infty}^{+\infty} S_{air}\ (X'',\ Z)\ \frac{1}{2\pi\sigma^2_{MCS}}\ e^{\frac{-(X-X'')^2}{2\sigma^2_{MCS}}}\ *$$

$$D_0(0,0,Z_{eff})\ \left[erf\frac{WX\phi Z/2}{\sqrt{2\sigma_0}}\right]^{-2}\ \left[\frac{SSD\ +\ Z_{eff}}{SSD\ +\ Z}\right]^2\ dX''$$

Note that no integration is carried out in the y dimension. This is a 2D calculation. Thus, blocking changes just above or below the plane of calculation will not be reflected.

Photon Contamination: Every clinical electron beam has a certain measure of photon contamination. Photon contamination is treated using a two-step process.

The first step is to extract that portion of the central axis depth dose curve which is due to photons. It is assumed that all dose beyond the electron practical range is due to photons. Obviously, some portion of the dose within the electron practical range must also be due to photons. At 0.5 cm beyond the practical range, the dose is used to extrapolate the photon dose component within the practical range. Extrapolation assumes that geometric divergence (inverse square) is the only attenuating process. This slightly overstates the photon contribution. The photon and electron components are then separated.

The second step is to reproject and add the photon dose into a patient calculation. The photon dose is assumed uniform across the beam and is looked up from the extracted data based on a calculation point's physical depth.

This is a simplistic way to consider photon dose. However, photon dose is a reasonably small effect. This approach should introduce only small errors in most cases.

Machine Parameters Required: The following data is required to characterize a given electron energy/accelerator combination.

Central Axis Depth Dose: The central axis depth dose distribution is measured by scanning a small volume chamber in a water phantom along the central axis of the beam and measuring relative rates of change generation.

Inherent direction variance is measured from penumbra data per Hogstrom's description.[5]

Inherent direction divergence ($\sigma_{\theta X}$) is determined from in-air penumbra measurements using film dosimetry. The penumbra is defined as the distance in centimeters between the 90% and 10% isodose lines along the edge of an open beam. Penumbra measurements are made in air at varying SSDs and plotted as a function of SSD. The data is fitted to a line whose slope is determined. The slope is multiplied by 0.391 to determine $\sigma_{\theta X}$.

Practical Range: The range of an electron beam is determined by extrapolating the linearly decreasing portion of the central axis depth dose distribution to the distance axis.

KEY TO VARIABLES

Z	=	Atomic Number
T	=	Electron Energy
T_0	=	Initial Electron Energy
σ^2	=	Variance of Direction of Travel
σ_{0X}	=	Initial Variance of Direction of Travel
Z, Z'	=	Depth of Travel Beyond Patient Surface
Z_{eff}	=	Effective Stopping Power Weighted Depth
R_p	=	Practical Electron range
$\left[\frac{dE}{dZ'}\right]$	=	Linear Collision Stopping Power in Medium
$\left[\frac{dE}{dZ'}\right]_{H_2O}$	=	Linear Collision Stopping Power in Water
σ^2_{AIR}	=	Variance of Direction of Travel in Air
L_0	=	Collimator to Skin Distance
σ^2_{MCS}	=	Variance of Direction of Travel Due to Multiple Coulomb Scattering
$\left[\frac{d\sigma^2_{MCS}}{dZ'}\right]$	=	Linear Angular Scattering Power
σ^2	=	Total Variance of Direction of Travel
S	=	Relative Pencil Beam Intensity, Generally Zero Under a Block and Unity in the Field
S_{air}	=	Electror Flux Density in Air
D_0	=	Central Axis Depth Dose of Open Square Field
$WX\phi Z$	=	Side Length of Open Square Field Projected to Depth
σ_0	=	Pencil Beam Direction Variance in a Water Phantom
SSD	=	Source to Skin Distance
M_0, M_1, M_2		Hogstrom's Moment Equations
ΔZ	=	Differential Depth

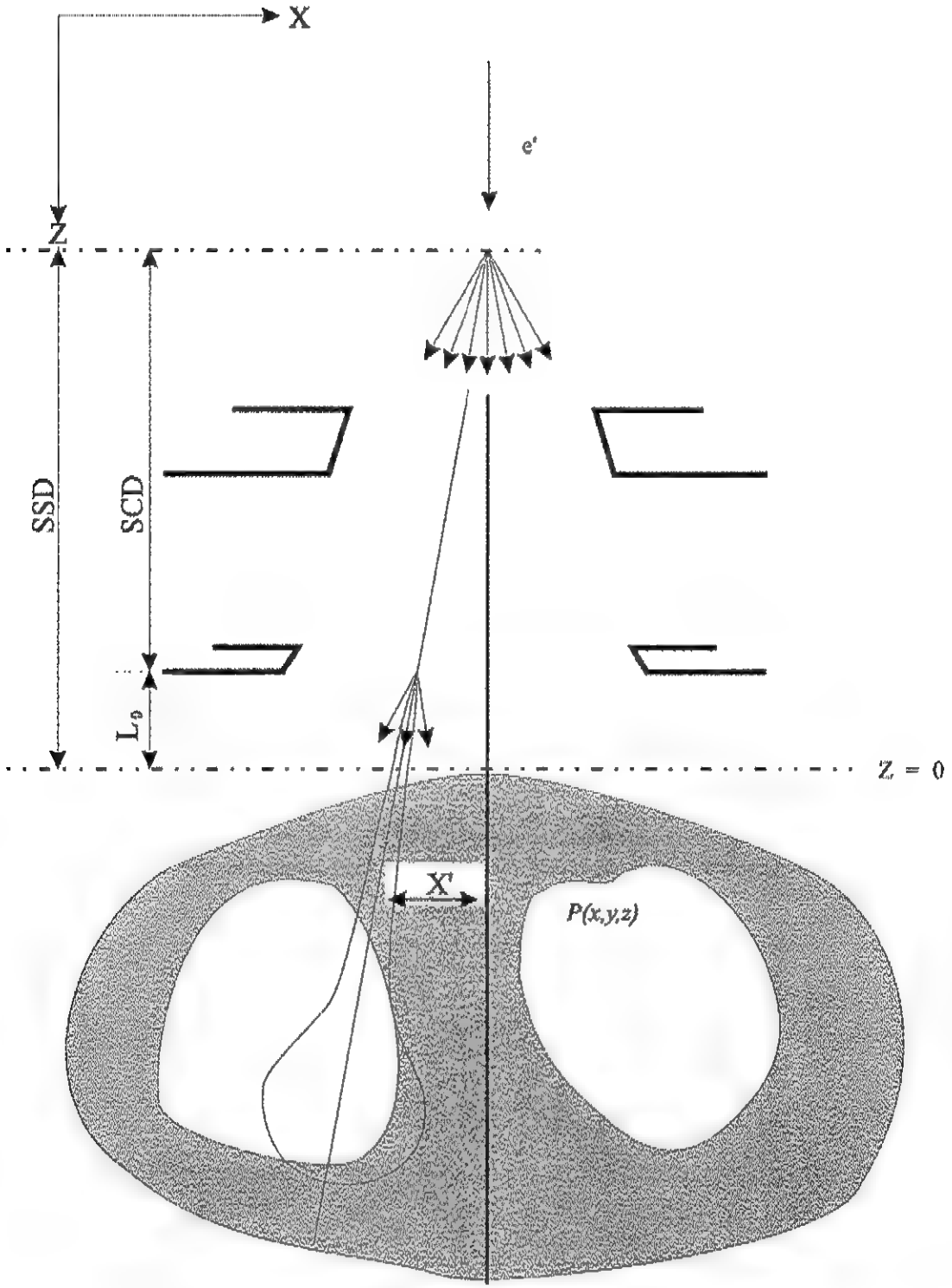


Figure 11.9 - Pencil Beam Calculation Geometry

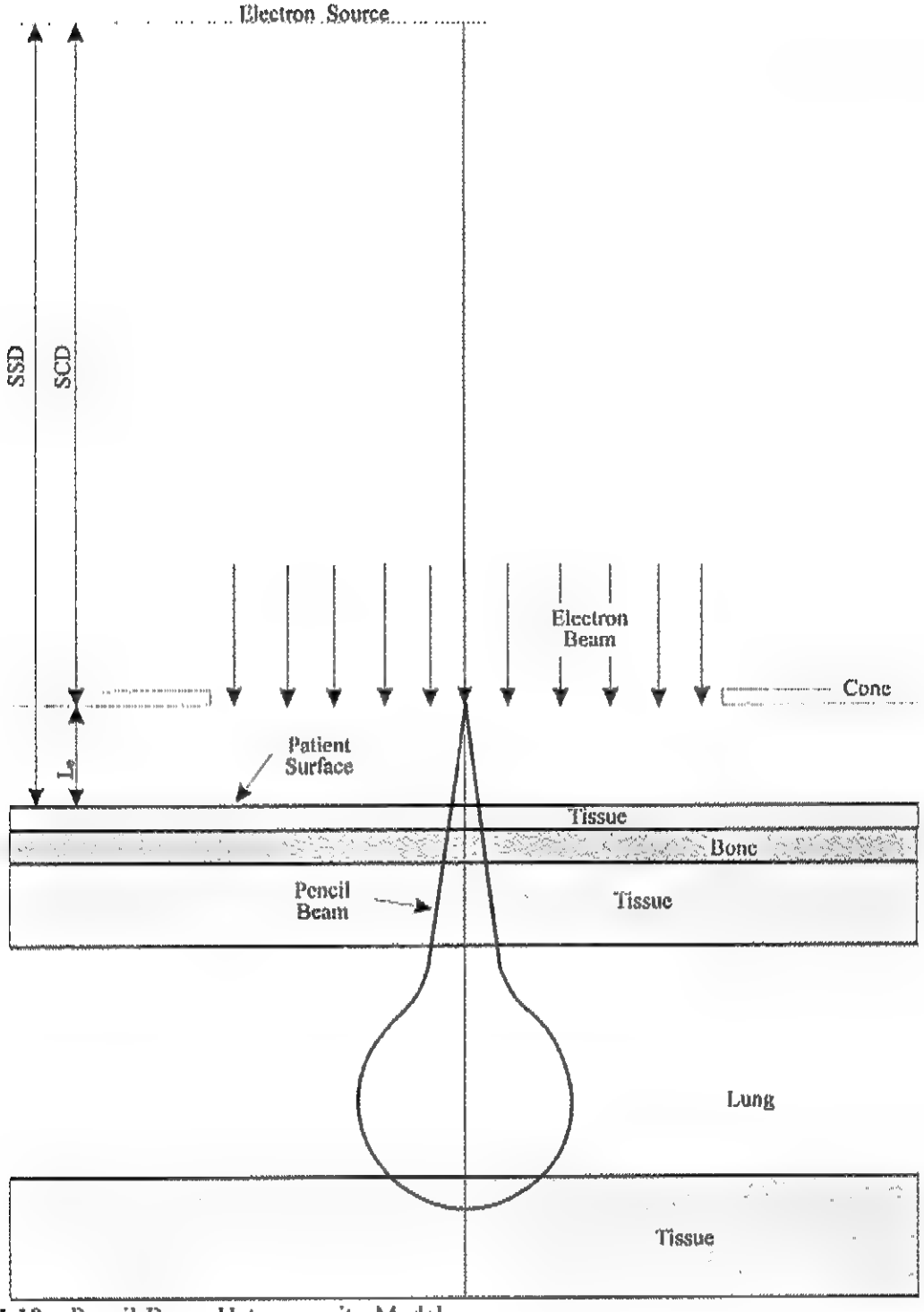


Figure 11.10 - Pencil Beam Heterogeneity Model

DAILY MONITOR UNIT CALCULATION PROGRAM

The daily monitor unit calculation program is intended for use when only doses along the central axis are of interest and secondary blocking is such that it can be represented by known effective field dimensions.

To calculate the machine setting required to deliver a dose to a point, the prescribed dose is divided by the current calibrated dose rate at the collimated field size; the TMR at the effective field size and depth; total transmission factor of trays, wedge, and compensator; and an inverse square correction from the calibration point to the calculation point. A shutter correction is added if applicable. The model is as follows:

$$Machine\ Setting = \frac{Dose}{CDR * INVSQ * Tf * Cf * Wf * OF(FS) * \frac{PSF(FS')}{PSF(FS)} * TMR(FS', D)} + SF$$

Where:
Machine Setting =monitor units or timer setting
Dose = prescribed dose in cGy at depth d_p and SSD
CDR = calibrated dose rate * Cobalt decay
Tf = block tray transmission factor
Cf = compensator transmission factor
Wf = wedge transmission factor
SAD_{ref} = source axis distance for specific machine (i.e., 80 or 100 cm)

$FS = \frac{2(Col\ x * Col\ y)}{Col\ x + Col\ y}$ = equivalent square of collimator field size

$FS' = \left(\frac{2(Eff_x * Eff_y}{Eff_x + Eff_y}\right)\left(\frac{SAD_{reff} + d_p}{SAD_{reff}}\right)$ = equivalent square for effective field size at depth

OF(FS) = relative output factor for collimator setting FS
d_{max} = depth of dose maximum
d = depth of point P
SF = shutter factor or timer error
PSF(FS) = Peak Scatter Factor for field size FS
TMR(FS', d) = Tissue Maximum Ratio for field size FS' at depth d_p
SSD = Source to Skin Distance at point P

IRREGULAR FIELD CALCULATION

The Irregular Field Calculation program is used to calculate machine settings and doses for fields which have significant secondary blocking. Doses are calculated at any point, either in an

open area or under a block. As many block edge types as necessary can be stored in the machine data file.

The shape of the field is entered using the digitizer. Each edge segment entered can have a different edge type. Points of calculation are also entered using the digitizer. Once the contour and point entry are complete; the SSD, depth, and name are entered for each calculation point. Finally, the machine collimator setting, tray transmission factor, point of dose specification and dose are entered. These entries can be edited later from the keyboard.

From this data, the dose to each calculation point is calculated and displayed on the screen. If the results are satisfactory, then they may be printed and plotted for permanent record.

The model used to find the dose at the calculation points is an extension of the model developed by Cunningham[1]. The primary dose is calculated from the zero area TMR's corrected for off-axis beam softening[2&4], beam profile, and block edge effects. Appropriate transmission factors are applied to points under blocks. The scatter dose component is calculated using the Clarkson[3] integration technique from the table of circular scatter maximum ratios.

The dose to any calculation point in the field can be calculated to within ±3% with accurate data. The present model assumes no scatter originates from under blocks, therefore, doses within ±1 cm of a block or under a block may be in error by as much as 5-6%.

The dose to point P is calculated from the following equation:

$$\frac{D(P)}{mu} = CDR * INVSQ * O(FS) * Tf * TMR * \frac{PSF(EQS)}{PSF(FS)}$$

Where:

$$INVSQ = \left(\frac{SSD_{CALIB} + d_{max}}{SSD_{CALIB} + g + d_p} \right)^2$$

$$TMR = \left[TMR(0, d_p)^{\frac{HVL(0)}{HVL(R)}} * E_i * P(R_i) \right] + \left[\overline{SMR}(d_p) \right]$$

The first term of the TMR is due to primary photons. The zero area TMR and, thus, the primary irradiation is modified for off-axis softening, edge attenuation, and off-axis intensity changes. The second term is due to scattered photons and is calculated using the Clarkson integration technique.

$$\overline{SMR(d_p)} = \frac{1}{360} * \sum_{i=1}^{360} SMR(r_i, d_p)$$

Note that when the total TMR is reported on a printed hardcopy, its value is calculated to be the sum of the zero over TMR (without modifying factors) and the SMR. This value cannot be used independent of the above equation for hand calculations.

After performing the Clarkson integration, Prowess returns an effective field size associated with each calculation point. This is determined by reverse interpolation of the calculated TMR into the machine's TMR table to determine what square field at this depth would result in the TMR seen at this point. If this interpolation is not possible (e.g., the calculation point is at or near d_{max}), an area/perimeter type calculation is made to determine the equivalent square of the effective field size.

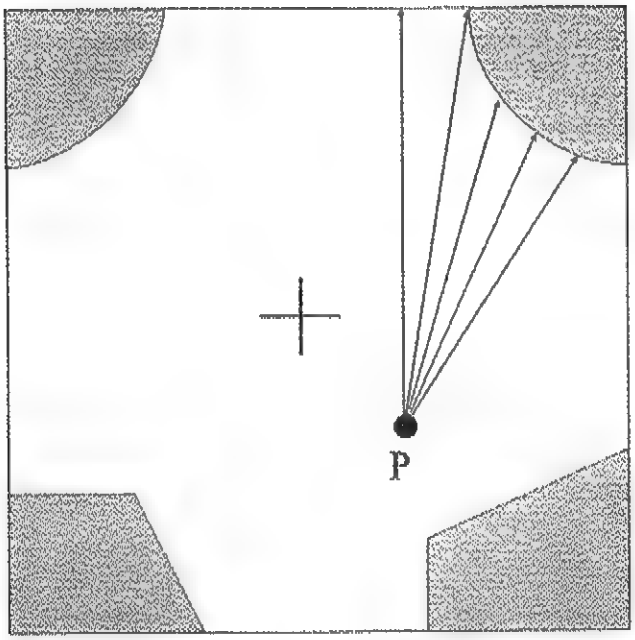


Figure 11.11 - Scatter Integration

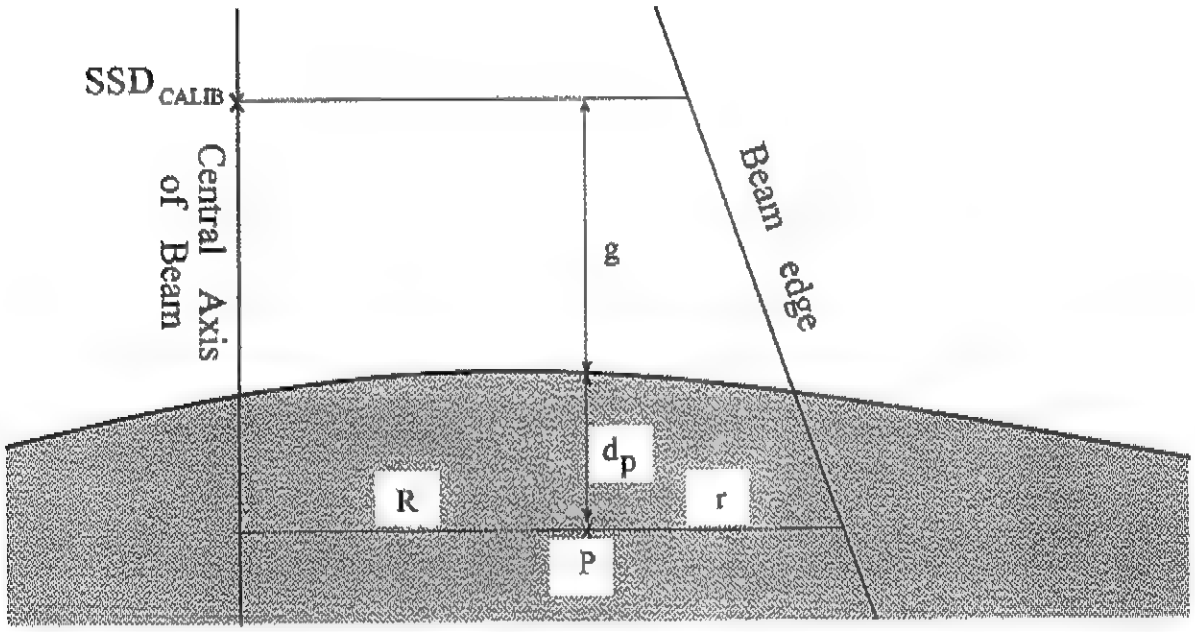


Figure 11.12 - Axial Geometry

Variable Names.

D(P)	=	dose to point P
Mu	=	treatment machine setting
CDR	=	calibrated dose rate under reference conditions
INVSQ	=	inverse square correction factor
SSD_{CALIB}	=	source to surface distance of calibration
d_{max}	=	depth of dose maximum along central axis under calibration conditions.
g	=	vertical gap between SSD_{CALIB} and skin surface at calculation point
d_p	=	vertical distance between skin and calculation point
O(FS)	=	output factor of collimator equivalent square
Tf	=	tray transmission factor
TMR	=	Tissue Maximum Ratio at calculation point
$TMR(0, d_p)$	=	zero area TMR at depth of calculation point
HVL(0)	=	good geometry half value layer in water of beam along the central axis
$E(r_i)$	=	edge transmission factor of nearest collimation device to the calculation point
$P(R_i)$	=	beam profile factor for point P
$SMR(d_p)$	=	average Scatter Maximum Ratio at point P
n	=	number of angles for scatter integration
r_i	=	distance at depth from calculation point to field edge at angle i
$SMR(r_i, d_p)$	=	Scatter Maximum Ratio of a circular field of radius r_i and depth d_p.
PSF(FS)	=	Peak Scatter Factor for field size FS
EQS	=	Equivalent Square of beam as calculated by the Clarkson integration

FS $= \dfrac{2(Col\ x\ * Col\ y)}{Col\ x\ + Col\ y}$ = *equivalent square of collimator field size*

Note that it is possible to specify edge factor data in such a way as to define a partial transmission block which can be entered as part of a field perimeter. However, since no scatter is assumed to originate under the field edge, this is not recommended.

BRACHYTHERAPY CALCULATION

The Brachytherapy Calculation Program calculates the dose rate to any point for seed and line sources. To calculate the dose distribution in a plane from an array of sources, the dose rate from each source is summed for an evenly spaced array. Size and spacing of the spacial array are determined by the user before calculating. The array size can be set between 100 and 4096 calculation points. The window of calculation can be changed from 2 x 2 cm into as large an area as necessary. After calculation, isodose lines are plotted by interpolating on the calculated matrix. Therefore, the larger the number of matrix points the more accurate the isodose curves. 1024 is (32 x 32), the default matrix size and this is accurate enough for most implants.

Orthogonal Film Entry

The coordinates from the orthogonal film entry procedure are derived by simple triangulation. No correction for changes in off-axis divergence is made. For a line source this error is minimized by error analysis and choosing the common Y coordinate that most closely approximates the true physical source size.

In order to correct for off-axis changes in magnification, two additional bits of information must be known about the films. 1) target to film distance or target to implant distance and 2) the exact orientation of the films. In most cases this information is not available. Incorrectly entering either of these items can double the length errors generated by ignoring the error.

Assuming the source to mid-implant plane is 80-100 cm and the maximum source distance from the magnification plane of a typical implant is 5 cm, the maximum positive error generated is 2-3 mm. Typically, this error will be no greater than 1-2 mm. The precision of the entry is better than ±1 mm and the accuracy is ±1-2 mm. The inaccuracies due to changes in magnification above and below are on the order of the accuracy. Therefore, the total accuracy can be expected to be ±2 mm.

In the evaluation process, after digitizing each film you are provided with a summary of the entry results. If the difference in Y coordinates is greater than ±2 mm between the two films then the sources are flagged. You may then re-enter these sources or accept them after analyzing the error.

Further, the Y or common axis coordinate of the two films are fit using a least square to a straight line. If the two sets of Y data are plotted on linear graph paper, you would see a line at 45 degrees through the origin. A line which does not pass through the origin is an indication of an unsatisfactory origin. The origin error must be removed before any subsequent change in magnification. When the line is not at 45 degrees this indicates that one or both films have magnification factors entered incorrectly. The ratio of these errors is shown at the bottom of the screen. A perfect fit between the two films would give a ratio of 1.000 with a variance of 0.000. If the magnification differs by <5%, (the ratio is between 0.95 and 1.05), then you may wish to proceed without further change. A variance or >0.05 is indicative of bad data entry. If this occurs you should consider re-entering all sources.

The effect of a 2-3 mm maximum source displacement at the edges will change the dose rate by no more than 2%, primarily at the edges of the implant.

To help you improve the entry of line sources the summary screen also shows the difference in calculated versus expected source length. If this differs by more than ±10% then the source is flagged.

General Model

The dose from a linear source is determined by a four point interpolation from a reduced polar coordinate dose table. The dose tables are generated for a specific source using physical parameters descriptive of the source or measured data. An inverse square law calculation correcting for scatter and absorption is used for seeds. Measured or Polynomial coefficients are used for absorption and scatter correction. To enhance the calculation speed, a precalculated table of dose values is generated prior to performing the implant calculation. The following sections describe the calculational models.

Seed Model

The dose rate D(P) to any point P is calculated by assuming the seed is a point source having spherical symmetry. For $0 \leq r \leq r_L$, K(r) is assumed to be a polynomial fit to the scatter and attenuation of the medium.[4] Beyond r_L, the attenuation becomes an exponential extrapolation to the tail of K(r).

To speed up calculations, a table of correction factors are precalculated and stored for each source type. The correction factor COR(r) is stored for discrete values of r from 0 to 40 cm. Beyond 40 cm, COR(r) is assumed to be unity.

Figure 11.12 depicts the geometry used through this calculation.

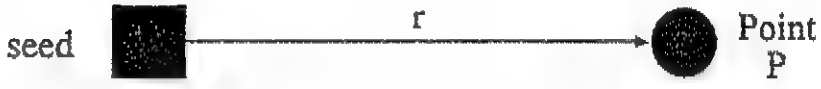


Figure 11.13 - Seed Source Calculation Geometry

The equation description for dose D(P) is as follows:

$$D(P) = \frac{A * \Gamma * C}{r^2} * atten(r)$$

For $r \le r_L$, *use Meisberger polynomial fit:* $atten(r) = K(r)$

For $r > r_L$, *use exponential extrapolation:* $atten(r) = K(0.75r_L) *$

Where:

A = *activity per seed*

$\Gamma = \frac{R}{hr * mCi}$ @ 1 *cm for the isotope*

$C = \frac{cGy}{R}$ *conversion for the isotope*

r = *distance from seed to point P (cm)*

r_L = *maximum range of the polynomial fit (cm)*

$atten(r)$ = *attenuation factor at distance r*

$K(r) = K_1 + K_2 * r + K_3 * r^2 + K_4 * r^3$ = *equation used to account for scatter and attenuation of media for* $r \leq r_L$

$$l(r) = 4.0 * ln \left[\frac{K(r_L)}{K(.75 r_L)} \right] * \left[\frac{r - (0.75 * r_L)}{r_L} \right]$$

K_1, K_2, K_3, K_4 = *Coefficients to account for scatter and attenuation.*[4]
i.e., the coefficients A, $B * 10^{-3}$, $C * 10^{-4}$, *and* $D * 10^{-5}$, *respectively in the source entry and edit program.*

To increase the speed of computation, a table of precalculated correction factors is generated. D(r) is then simplified into:

$$D(r) = \frac{A}{r^2} COR(ir)$$

Where

$IR(r)$ *is an arbitrary, invertible function*

$$IR(r) = \left[\frac{1000.0}{r^2 + 10.0} \right] \qquad 0 \leq ir \leq 100$$

$$\text{and } r = \left[\left[\frac{1000.0}{ir} \right] - 10.00 \right]^{1/2} \qquad 0 \leq r \leq 40 \text{ cm}$$

$$\text{and } COR(ir) = \Gamma * C * atten(r)$$

= *correction factor at distance r.*

COR(ir) is precalculated for integer values of ir. For any distance r, the equivalent ir can be found and the correction value calculated by linear interpolation from the COR(ir) table.

For example, at r = 4.0 cm

$$IR(r) = 38.46$$

Therefore:

$$D(r) = \frac{A}{r^2}\left[COR(38) + .46\ (COR(39) - COR(38))\right]$$

Line Model

The dose rate D(P) to any point P is calculated by assuming a line source is cylindrically symmetric. The dose to point P is found integrating over the activity along the line source. Attenuation and scatter through the source itself, clad material, and media are accounted for.

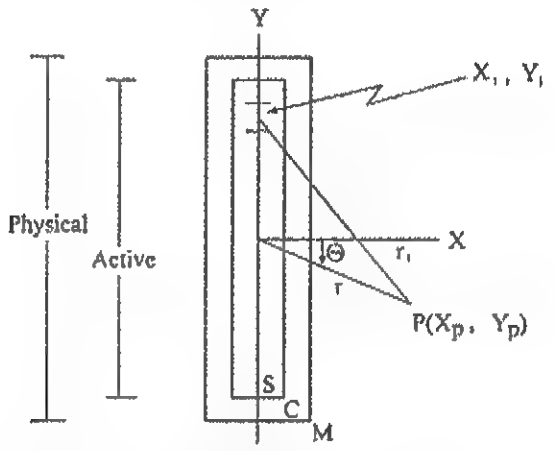


Figure 11.14 - Line Source Calculation Geometry

Figure 11.14 describes the geometry for the calculation. The source is assumed to be symmetric about the middle of the cladding area. Published data[12] shows this assumption to produce errors no greater than 3%.

Area S contains the source material, Area C is the cladding, and area M the medium or patient. r is the distance from the center of the source to point P at an angle of $\emptyset$ from the perpendicular.

As in the seed model the scatter and attenuation through the medium or the correction factor K(r) is described by a polynomial from 0 to r_L cm. Beyond r_L the correction is an exponential extrapolation to the tail of K(r). The attenuation through the source and cladding is assumed to be exponential.

The equation describing D(P) is as follows:

for $r \le r_L$

$$D(P) = \sum_{i=1}^{N} \frac{A * \Gamma * C}{N * r^2} * e^{-\mu_s(r_s - s)} * e^{-\mu_c(r_c - c)} * K(r_M)$$

for $r \ge r_L$

$$D(P) = \sum_{i=1}^{N} \frac{A * \Gamma * C}{N * r^2} * e^{-\mu_s(r_s - s)} * e^{-\mu_c(r_c - c)} * K(.75r_L) * e^{-\mu(r_M)}$$

Where

N = *number of discrete increments into which source is divided*

Typically 15 from $-\frac{Active}{2}$ *to* $+\frac{Active}{2}$

A = *total activity in mCi (or mg Rad eq) per line source*

$\Gamma = \frac{R}{hr\ mCi}$ @ 1 *cm for the isotope*

$C = \frac{cGy}{R}$ *conversion for the isotope*

r = *distance from center of source to point P (cm)*

Θ = *angle from perpendicular to r*

r_L = *maximum range of the polynomial fit (cm)*

$K(r) = K_1 + K_2 * r + K_3 * r^2 + K_4 * r^3$ = *equation used to account for scatter and attenuation of the media for* $r \le r_L$

$$I(r) = 4.0 * \ln\left[\frac{K(r_L)}{K(.75r_L)}\right] * \left[\frac{r_C - (0.75 * r_L)}{r_L}\right]$$

$r_t = r_s + r_C + r_M$ = *distance from point of integration or segment to point P*

μ_s = *attenuation coefficient through clad material* (cm^{-1})

r_S = *thickness along integration radius through source (cm)*

s = *thickness of source on central axis (cm)*

μ_C = *attenuation coefficient through clad material* (cm^{-1})

r_C = *thickness along integration radius through clad (cm)*

c = *thickness of clad material (cm)*

Active = active length of source (cm)

Physical = physical length of source (cm)

To increase the speed of computation, a table of precalculated factors is generated. This table is a two dimensional array in radius and angle. The dose rate to point P becomes:

$$D(P) = \frac{A}{r^2} L(r, \theta) = \frac{A}{r^2} * L(dt)$$

Where

$$r = \left[\left(\frac{350.0}{ir}\right)^{1/2} - 10.0\right] - 1.0$$

$$ir = \frac{350.0}{(r - 10.0)^2 + 10.0} \qquad for \quad 0 \le r \le 25 \ cm, \ 0 \le ir \le 33$$

$$ith = 10.0 * \cos\theta \qquad for \quad 0^\circ \le \theta \le 90^\circ, \ 0 \le ith \le 10$$

$$dt = ir + 34 * ith$$

EXTERNAL BEAM REFERENCES

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SAMPLE CALCULATIONS

EXTERNAL BEAM

This section describes entry of an external beam treatment plan using a four field box, bilateral arcs, and a wedged pair CT plan. Use the plotted results as a template to duplicate the contour which is included at the end of this chapter.

Four Field Box

- Place the contour under the plastic sheet on the digitizer table. Before entry, be sure that all tumor volumes, points of calculations, reference points, etc. are marked on this contour.

- Select External Beam Calculation from the main menu.

- Enter the following patient demographics:

Patient Name:	Don Grady
Patient Number:	12345
Physician Name:	Dr. Hansel
Plan Prepared by:	Your Name
Treatment Site:	Pelvis
Comment:	Any Comment

- Choose Outline. Respond to the prompt: "Enter magnification from the digitizer Y or N?" - In this case, "N" since it is scaled 2:1. Enter magnification by selecting the value of 0.50.

- Using the digitizer pen, digitize point "U" in the upper left corner and point "L" in the lower right corner. Digitize origin and a point to the right on the X axis.

- Enter the outside patient contour by tracing the pen around contour. End by touching the digitizer box labeled End.

- Enter the tumor volume by touching the digitizer box labeled Tumor. Proceed to enter tumor volume. End entry by touching the digitizer box labeled End.

- Enter three triangulation points by touching digitizer box labeled Reference Pts and entering the points to the anterior, left, and right. End by touching digitizer box End.

- Enter calculation points by touching the digitizer box Calculation Pts, enter the isocenter as a calculation point.

- Exit digitizer by touching the Exit box.

- Input the densities and names of any areas you entered. Press Enter.

- Enter the name of the calculation points.

- Enter the name of the contour.

Add the beams to the contour by selecting Plan.

- Add a new beam by selecting Beam.

Select a treatment machine from the list.

- Enter the following new beam data:

Machine:	Linac 15X
Beam Type:	Isocenter
Wedge No.:	0
Beam Name:	Anterior
Col Width cm:	11.000
Col Length cm:	12.000
Eff Width cm:	10.000
Eff Length cm:	10.000
Weight Value:	30.000
Fraction:	25
Tray Factor	0.98

- Select Accept. The beam appears on the screen. Select BmDisp to display the beam description on the bottom of the screen. Select BmRot and CngAngl. Enter 180. You have now entered the anterior field.

- Enter Beam Number 2 by selecting Beam. Choose a new beam accepting New. Select CopyInv and choose beam 1. Edit the name of the beam, "posterior." Accept the beam.

- Enter beam 3 and 4 by using the same technique as beams 1 and 2. Enter the angles at 90° and 270° and edit names to RT lateral and LT lateral, respectively.

- Following the entry of these four beams, select Calcul to calculate the dose distribution. After the calculation finishes, the dose distribution is presented.

- Select the isodose 100, 95, 90, 80, 60, and 40%. Select ESCape to end.

- Enter the prescription by selecting Prescri. Enter a total dose of 5000 cGy to the 95% isodose line.

- Select Prt/Plt to print and plot and enter plot title, paper size, and plot orientation.

- Save the plan by selecting File, then Save. Enter a new plan name.

- Select Quit.

The results of this calculation are shown in Figures 12.1 through 12.3.

Bilateral Arcs

A pelvis contour is already entered. Now plan a pair of bilateral arcs.

- Select External Beam Calculation from the main menu.

- Press the down arrow to display the patient files available. Select the patient named GRADY. Choose Plan.

- Select Beam and select a treatment machine. Enter beam number 1 by filling in the new beam window.

- Change the beam type by selecting BmType then Rotate. Enter the following new data and select Accept.

Machine:	Linac 6X
Beam Type:	Rotate
Wedge No.:	0
Beam Name:	Rt Lat
Col Width cm:	8.000
Col Length cm:	8.000
Eff Width cm:	8.000
Eff Length cm:	8.000

Weight Value:	50.000
Fraction:	25
Tray Factor	0.95

- The beam will appear on the screen. Choose BmRot to change the start and stop angles.

- Choose StrtAgl and enter 30. Select End Angl to enter stop angle. Enter 150 to produce a 120° arc. Select ESCape to return to the Beam menu.

- Enter Beam Number 2 by selecting Beam and choose CopyInv. Change title to Left Lateral and select Accept. Check the angles to be sure they are appropriate.

- Calculate by choosing Calcul and wait for the calculation to complete.

- Select isodose values of 100, 95, 90, 80, 60, 40, and 30.

- Enter the prescription by selecting Prescri. Enter a total dose of 4500 cGy to the 95% isodose line.

- Print and plot this by selecting Prt/Plt. Enter plot title, paper size, and orientation.

- Save the plan by choosing File. Press ESCape to return to the planning menu.

- Select Quit to exit the program and return to the main menu.

The results of this calculation are shown in Figure 12.4 through 12.6.

Wedged Pair

- Enter three isocenter points by choosing the menu item labeled RefPt and enter the points to the anterior, left, and right. End by clicking the right mouse button or the End key.

- Enter calculation points by the menu item CalcPt. Enter the center of the tumor as a calculation point.

- Input the densities and titles of any areas you entered by choosing ChgDens.

- Complete the contour entry by choosing PrevMnu. You may add beams by selecting Plan.

- Add a new beam by selecting Beam. Select a treatment machine from the list. Enter the following new beam data:

Machine:	Linac 4
Beam Type:	Isocenter
Wedge No.:	0
Beam Name:	Lt Ant Ob
Col Width cm:	7.000
Col Length cm:	7.000
Eff Width cm:	7.000
Eff Length cm:	7.000
Weight Value:	1250.000
Fraction:	25
Tray Factor:	1.00

- Select Accept and the beam appears on the screen.

- Select BmDisp to display the beam description on the bottom of the screen. Using the mouse, rotate the beam to 191°.

- Add a wedge by selecting Wedge. Using the mouse, select the 45° wedge, clockwise.

- Move the isocenter with the mouse to the center of the tumor (maxillary antrum).

- Enter Beam Number 2 by selecting Beam. Choose a new beam selecting New. Select CopyInv and choose beam 1. Edit the name of the beam "Lt Ant Ob." Rotate the beam to 97°.

- Following the entry of these beams, select Calcul to calculate the dose distribution. Normalize to the maximum.

- Select the isodose curve values of 95, 90, 80, 60, and 40. Press ESCape to end.

- Enter the prescription by selecting Prescri. Enter the total dose of 4500 cGy to the 95% isodose line.

- Select HardCpy and Print to print. Chose ImagPrt to hardcopy the CT image.

- Save the plan by choosing File. Press ESCape to exit the current plan.

- Select Quit to exit from the program.

The results of this calculation are shown in Figures 12.7 through 12.10.

IRREGULAR FIELD

This section describes calculation of an irregular field using the irregular field program. The field is a mantle used to treat Hodgkin's Disease. Use the field shape enclosed at the end of this section as the beam outline for a sample case.

- Place the contour under the plastic film on the digitizer.

- Measure or enter the magnification of the field from the scale markings.

- Mark the points of calculation on the film and record the SSD and depth of calculation for each point.

- Mark the type of beam blocking at each edge of the field.

- Start the program by selecting Irregular Field Calculation from the main treatment planning menu.

- Enter the following patient demographics:

Patient Name:	Grady, Donald
Patient Number:	12345
Site:	Anterior Mantle
Physician's Name:	CJ
Plan Prepared By:	Your Name
Comment:	Any Comment

- Press Outlin.

- Select a machine from the list of those available.

- Enter the magnification.

- Proceed through the calibration by touching points "U" and "L" with the stylus on the digitizer.

- Digitize the origin at the central axis of the beam and a point on the major axis to the right of the origin on the axis of the beam.

- The default value for the edge type is set to collimator. Touch the digitizer box labeled Collimator Type to change the collimator type. Select the type of beam edge from the screen.

- Enter the shape of the field point by point. You may enter it in either direction.

- Touch digitizer box labeled End when you are finished.

- Now enter the calculation points. Once these are completed, touch digitizer box labeled End.

- You have now completed digitizer entry for this program. Touch digitizer box labeled Exit.

- Enter the SSD, depth, and description of each calculation point.
  Point 1, SSD: 100.0 cm, Depth 10.0 cm, Description: CA
  Point 2, SSD: 105.0 cm, Depth 5.0 cm, Description: Neck
  Point 3, SSD: 101.0 cm, Depth 9.0 cm, Description: Axilla
  Point 4, SSD: 94.0 cm, Depth 14.0 cm, Description: Lower

- Edit field parameters.

X Collimator size:	28.000 cm
Y Collimator size:	30.000 cm
Calculation Point:	1
Dose (cGy):	90.000
Tray Factor:	0.970

- Press Calcul to calculate the irregular field. The calculation summary for each point will appear at the bottom of the screen. Press any key to continue.

- Select Print to print. Select Plot to plot the results. Enter "Anterior Mantle" as title, scale factor of 0.5, and Y to 8½"x11" paper size.

- Select Quit to exit the Irregular Field program and return to the main treatment planning menu.

The results of this calculation are shown in Figures 12.11 through 12.12.

SECTION TWELVE
Sample Calculations

BRACHYTHERAPY

The calculation of two types of implants will be illustrated in this section. The first will be a typical gynecological cervix implant using five ^{137}Cesium sources. The second case will be a two plane, 32 seed, ^{192}Iridium used for a breast boost. Scaled templates for these cases are included at the end of this section to duplicate the results as they are shown in the samples.

Cesium Cervix

For this cesium implant, you will use a standard Fletcher Suit applicator with a loading of 20, 15, and 10 mg sources in the tandem and two 15 mg sources in the ovoids.

You will need two orthogonal films, one AP, and one lateral in order to input the source coordinates or use the template provided at the end of this chapter. Set the two films side-by-side (common axis vertical) under the plastic cover of the digitizer. Be sure that the ends of the sources are visible and numbered. Match the AP and lateral sources and points of calculation such as A_{Rt}, A_{Lt}, B_{Rt}, B_{Lt}, Bladder, and Rectum.

- Start the program by choosing Brachytherapy Calculation from the main menu.

- Enter the following patient demographics and select Accept:

Patient Film Name:	Masters
Patient Name:	Masters, Lilly
Patient Number:	12345
Site:	Cervix
Physician:	CJ
Plan Prepared By:	Your Name
Comment:	Any Comment

- Select Orthog to enter coordinates from film. Enter the source code Chose ^{137}Ce 3M 6D6C (type 1). Enter the source strengths in mg Ra eq which, for source 1, is 20.

- Answer the question "Enter magnification from the digitizer? Y or N?" Enter N. Enter the magnification factor of the localization films by entering 1.0 for both films.

- Go through the calibration procedure for the digitizer by sparking points "U" and "L." Digitize the origin of film one and a point to the right on the film axis.

- View the split screen. The coordinates for the first film will be on the right. The coordinates for the second film will be on the left. Digitize the coordinates of source 1.

- To change the strength of source number 2, touch the digitizer box labeled Change and enter the source type 1 and source strength 15 mg Ra eq from the keyboard. Digitize source 2.

- To change the strength of source 3, touch digitizer box labeled Change and enter the source type 1 and source strength 10 mg Ra eq on the keyboard. Digitize source 3.

- To change the source for the last time, touch digitizer box Change and enter the source type 1 and source strength 15 mg Ra eq. Since both ovoids are the same strength, digitize the two ovoids. If there are points of calculation, touch digitizer box Calculation Pts and enter them in order. Touch the digitizer box End to complete film one.

- Move to film number two. Digitize the origin and a point to the right and digitize the sources. There is no need to change and reenter the source strengths as they were entered from film 1. Enter the names of the calculation points.

- A summary of the sources are displayed on the screen along with the Y-axis error summary. Looking at the magnification difference and the variance shown in the system window, you should find the magnifica-tion difference is near 1.0 and the variance is near 0. Press Enter to proceed. Respond to the question "Save information?" Enter Y.

- Select the first view to calculate by pressing Plane. Three views appear on the screen. The largest view shows the AP projection. This is the plane of calculation. View A shows the transverse projection. View B is the lateral projection.

Since you should be satisfied with this calculation plane, you may calculate by selecting Calcul. As the program calculates the dose from a source, the point numbers appear on the screen.

- After calculating all five sources, the default isodose curves appear in the upper left window. Plot these curves on the screen by accepting the default values by pressing Enter after each number. After completing the display, press ESCape.

- Print the results by selecting Print. Plot the results by selecting Plot. Accept the displayed isodose values with an ESCape. Enter the plot scale factor of 1.0 and plot on the left side of an 8½"x11" paper.

- Select SwapB to move the lateral plane in the calculation window. Repeat steps 20 through 24 to calculate and display. Plot the plane on the right side.

- Following the print/plot process, press ESCape and then select Quit to exit the program and return to the main menu.

The results of this calculation are shown in Figures 12.13 through 12.16.

The results are presented on two pages: A written description and a graphical description. On the written page is a description of the radiation source in the implant including location, type, and activity. The name and location of each calculation point is also given. A table of dose or dose rate is included for each calculation point. The table includes total dose to each point and the contribution to each point if there are no more than 10 sources.

The graphical page(s) show the dose distribution for the calculational planes specified. One plane per page is shown. Each page gives angle and offset of plane. It shows the projection of the sources and a perpendicular view to illustrate offset. The isodose lines are shown in a unique color for each value.

Iridium Interstitial

This case is a two-plane ^{192}Ir seed implant with 16 seeds per plane. Source strength is 0.40 mg Ra eq.

You will need two orthogonal films, one AP, and one lateral (or use the enclosed template located at the end of this chapter). Set the two films side-by-side (common axis vertical) under the plastic cover on the digitizer light box. Be sure the sources are visible and numbered. Match the AP and lateral sources.

- Choose Brachytherapy Calculation from the main menu to start the program.

- Enter the following patient demographics and select Accept.

Patient File Name:	Smith
Patient Name:	Smith, Mary

Patient Number:	12345
Site:	Lt Breast
Physician:	CJ
Plan Prepared by:	Your Name
Comment:	Any Comment

- Select Orthog to enter one film at a time. Entre the source types. Choose ^{192}Ir seeds (type 106). Enter the source strength as 0.40 mg Ra eq.

- Answer the question: "Enter magnification from the digitizer Y or N?" Answer N. Enter the magnification factor of localization film by entering 1.0 for both films.

- Calibrate the digitizer by sparking points "U" and "L." Digitize origin of film one (on right) and a point to the right on the film axis.

- View the split screen. The coordinates for the first film will be on the left. The coordinates for the second film will be on the right. Digitize the coordinates of all 32 sources. Touch digitizer box labeled Ene.

- Go to film two. Digitize the origin, digitize a point to the right, and digitize in the sources. Touch digitizer box labeled Exit to end the digitizer entry. There is no need to change and reenter the source strengths.

- Once you are finishing digitizing the sources, a summary of the sources are displayed on the screen along with the Y axis error summary. Look at the magnification difference and the variance shown in the system window. You should find that the magnification difference is near 1.0 and the variance is near 0. Press Enter to continue.

- Respond to the prompt "Save these coordinates, Y or N?" Enter Y. Select Plane to select the first view for calculation. Three views appear on the screen. The largest view shows the AP projection. This is the plane of calculation. View A shows one perpendicular projection. View B shows another perpendicular projection.

- If you are satisfied with this calculation plane, you may calculate now by selecting Calcul. As the program calculates the dose from each source, the source number appears on the screen.

- After calculating all 32 sources, the default isodose curves appear in the upper left window. Plot these curves by selecting 10, 20, 30, 40, 50, and 60 cGy/hour. After completing the plot, press ESCape.

- Print out the results by selecting Print. Plot the results by selecting Plot. Accept the displayed isodose values with an ESCape. Enter the title "mid-plane." The plot scale factor as .0.

- Select SwapA to display the lateral plane. Repeat steps 17 through 21 to calculate and display. Plot the plane on the right side using the title "Transverse" and a scale factor of 2.0.

- Following printing and plotting, press ESCape to reach the main menu and then select Quit to exit the program and return to the main menu.

The results of this calculation are shown in Figures 12.17 through 12.20.

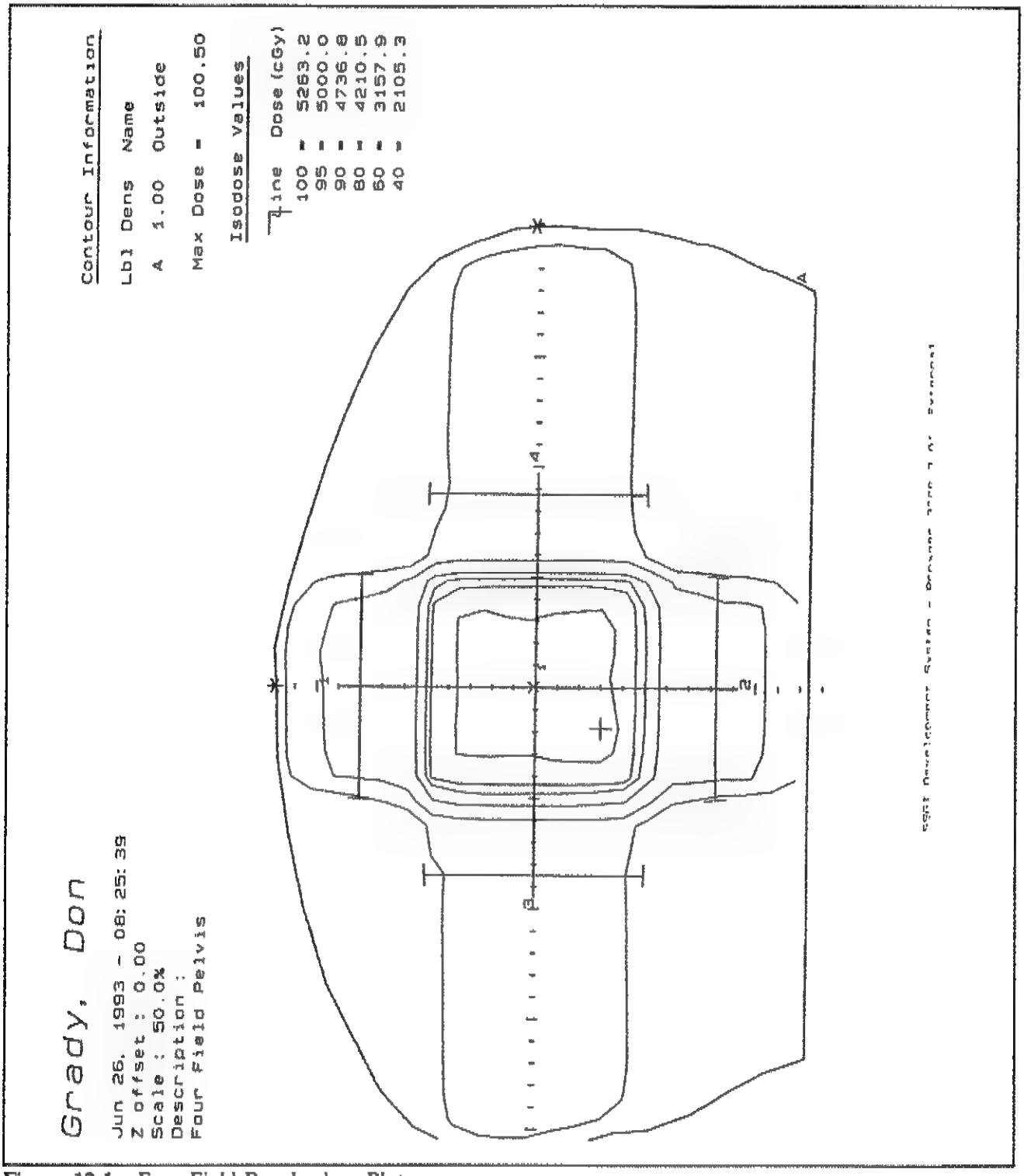


Figure 12.1 - Four Field Box Isodose Plot

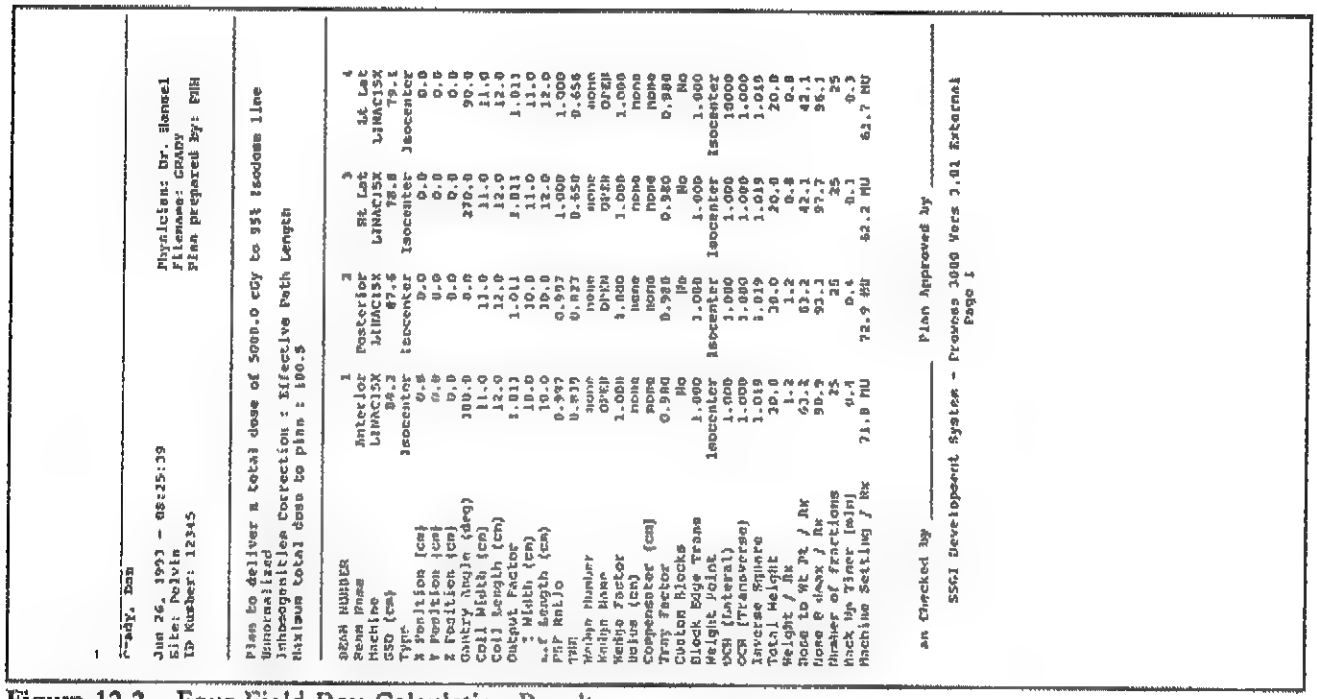


Figure 12.2 - Four Field Box Calculation Results

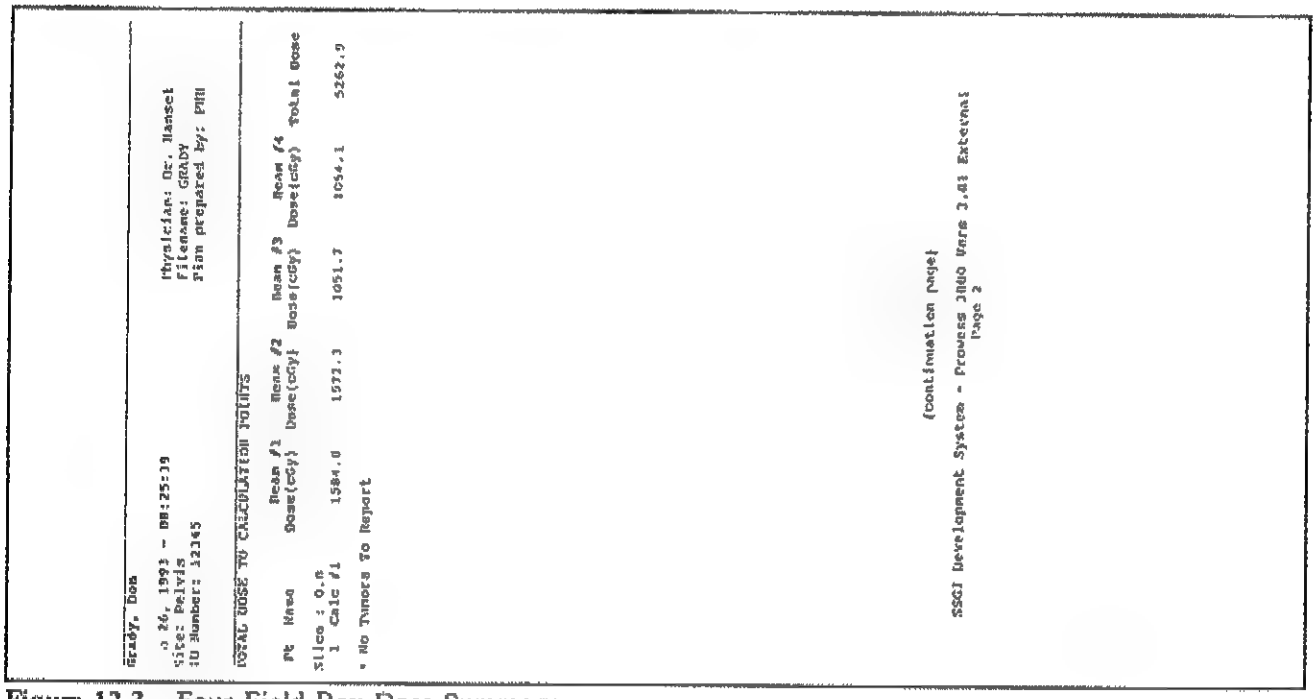


Figure 12.3 - Four Field Box Dose Summary

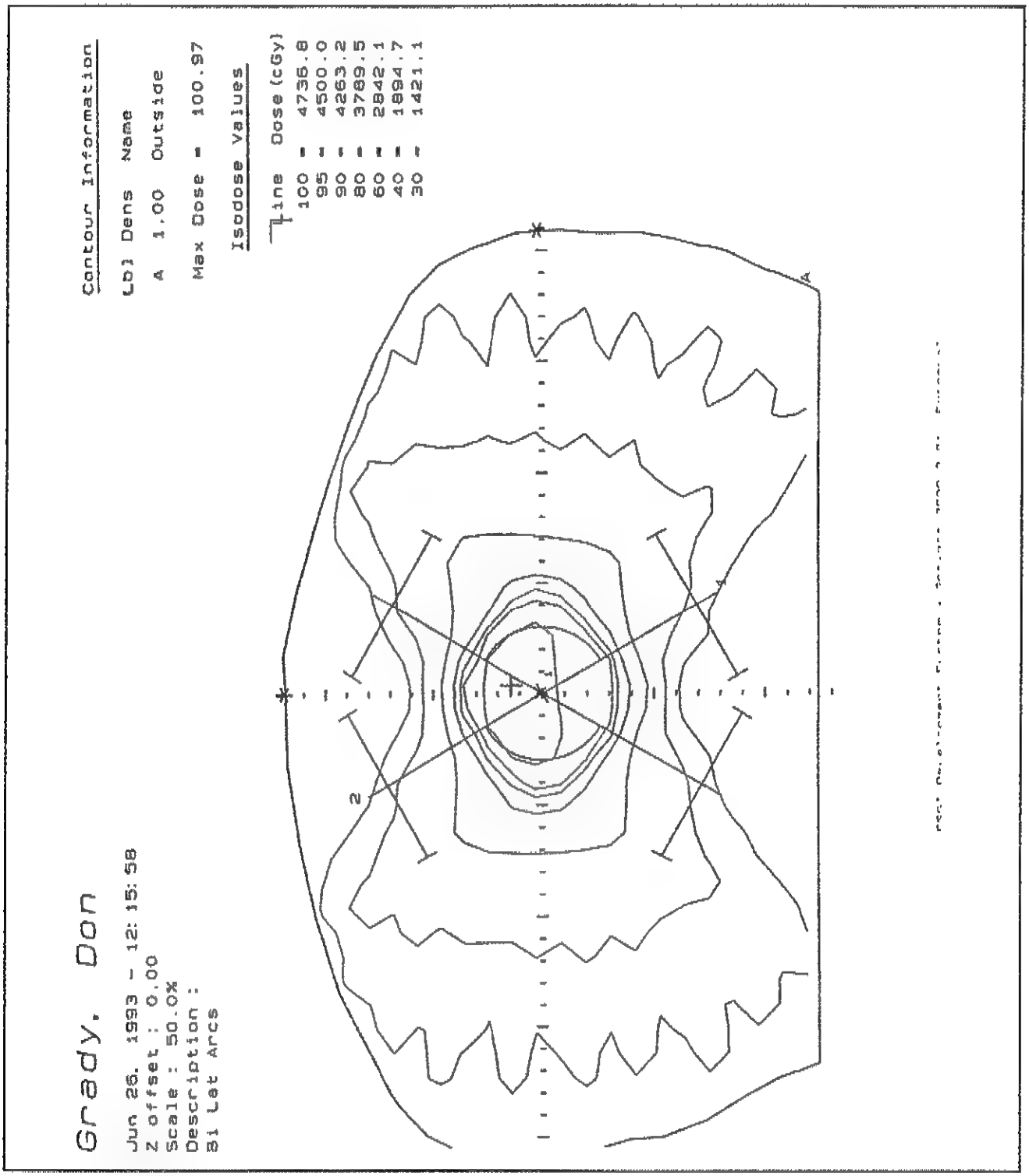


Figure 12.4 - Bilateral Arcs: Isodose Plot

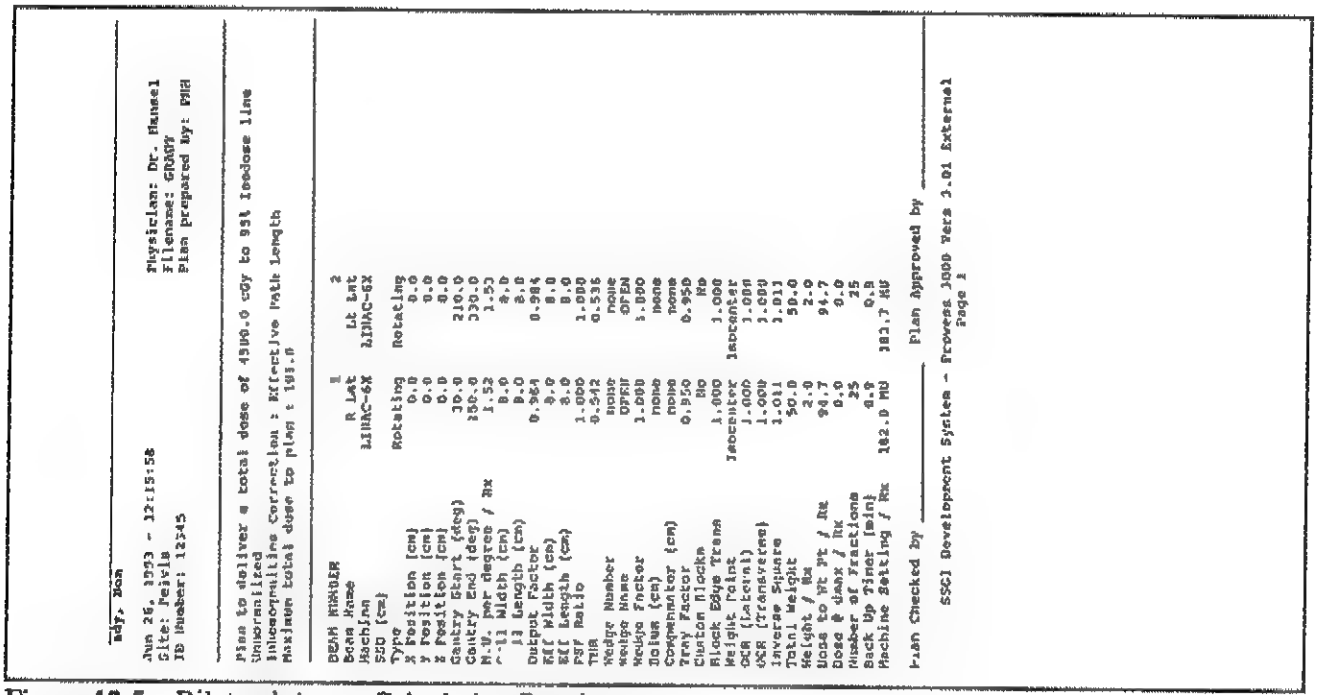


Figure 12.5 - Bilateral Arcs: Calculation Results

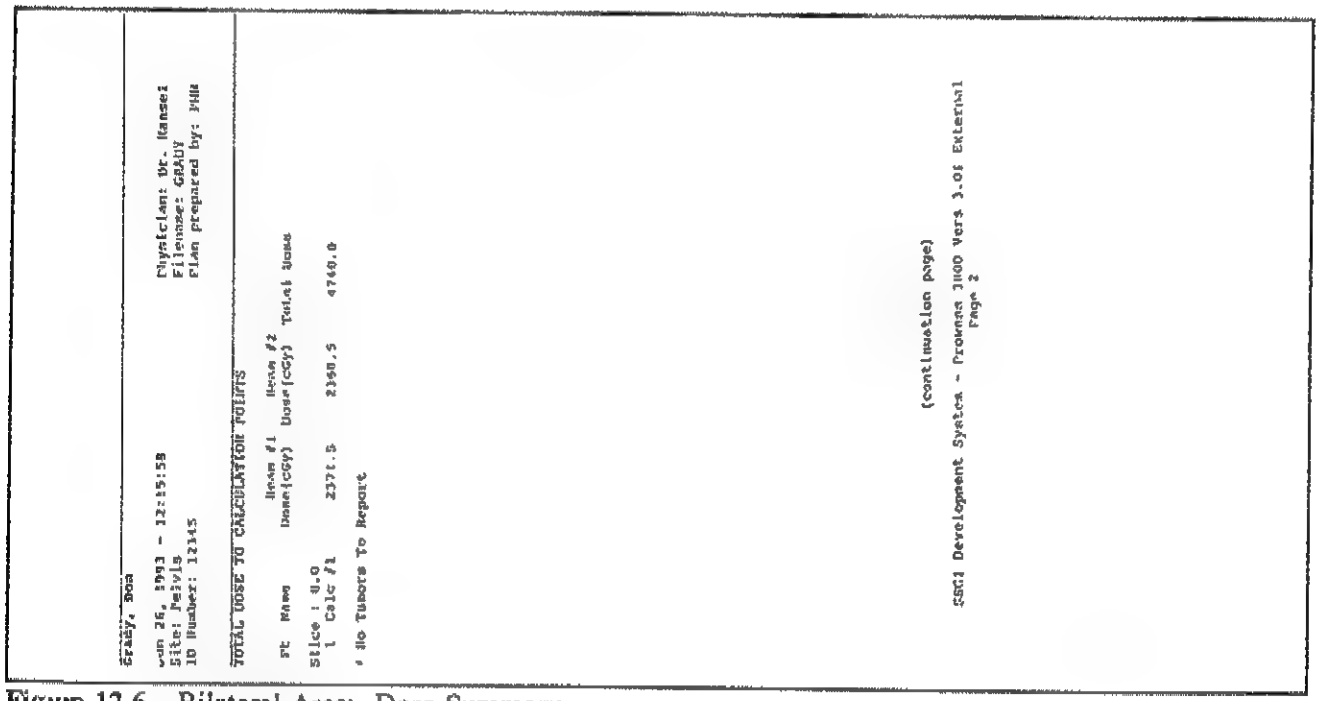


Figure 12.6 - Bilateral Arcs: Dose Summary

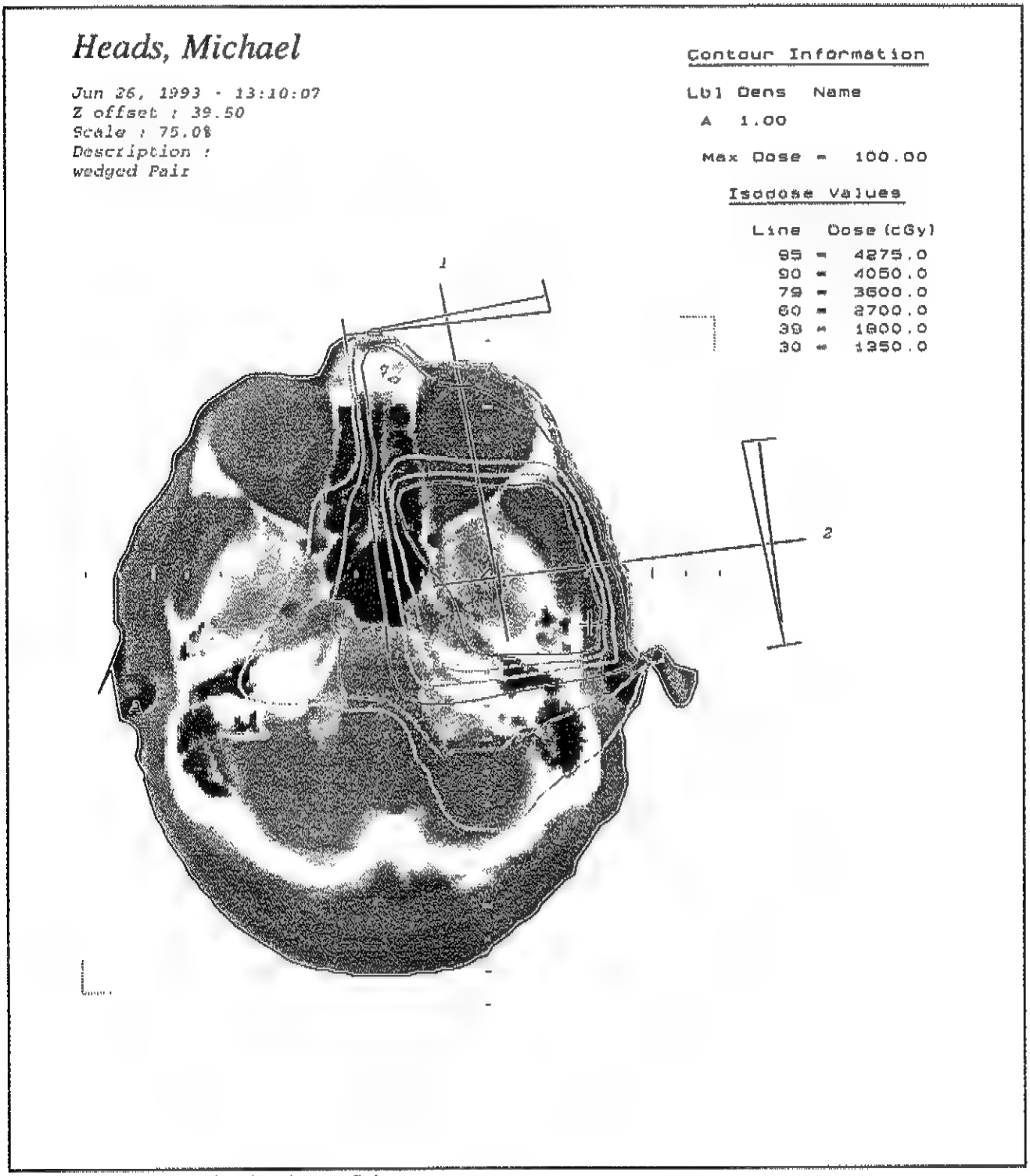


Figure 12.7 - Wedged Pair: Image Print

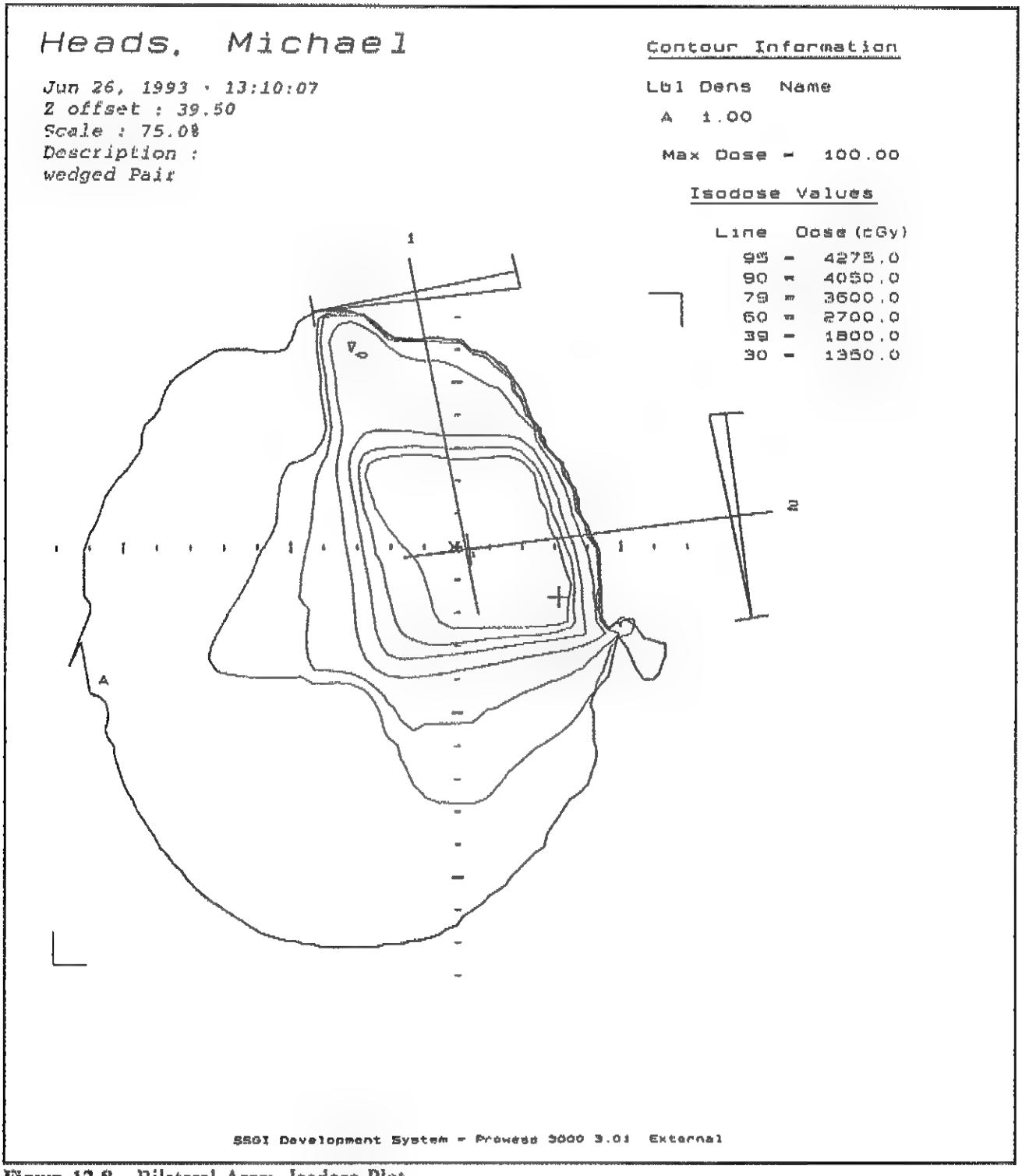
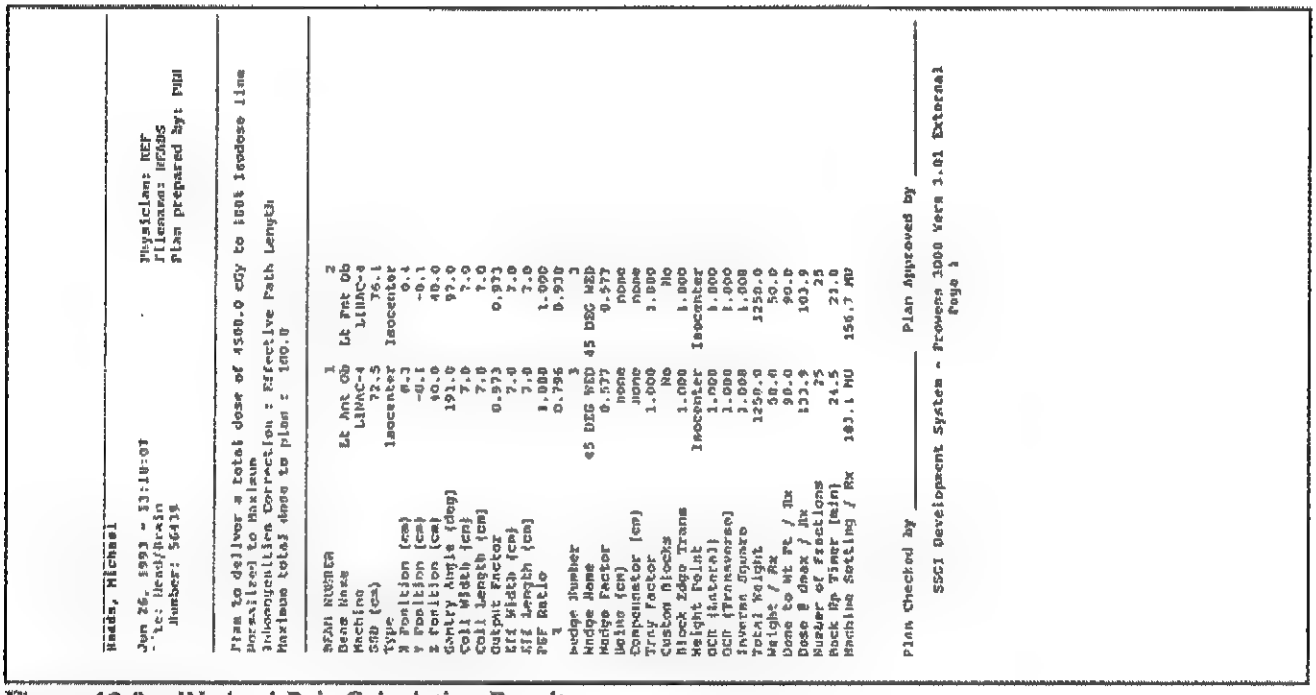


Figure 12.8 - Bilateral Arcs: Isodose Plot



```
Wedge, Michael

Jun 26, 1993 - 13:10:07                    Physician: REF
Site: Head/Brain                           Filename: WEDGE
Number: 56419                              Plan prepared by: PWM

Plan to deliver a total dose of 4500.0 cGy to 100% isodose line
Normalized to Maximum
Inhomogeneities Correction : Effective Path Length
Maximum total dose to plan : 160.0

BEAM NUMBER                        1          2
Beam Name                     Lt Ant Ob  Lt Pst Ob
Machine                         Lilac-4    Lilac-4
GAB (cm)                           72.5       76.1
Type                          Isocenter  Isocenter
X Position (cm)                     0.3        0.4
Y Position (cm)                    -0.1       -0.1
Z Position (cm)                    90.0       40.0
Gantry Angle (deg)                191.0       97.0
Coll Width (cm)                     7.0        7.0
Coll Length (cm)                    7.0        7.0
Output Factor                     0.973      0.973
Eff Width (cm)                      7.0        7.0
Eff Length (cm)                     7.0        7.0
PDF Ratio                         1.000      1.000
  X                               0.796      0.930
Wedge Number                          3          3
Wedge Name                   45 DEG WED 45 DEG WED
Wedge Factor                      0.577      0.577
Wedge (cm)                         none       none
Compensator (cm)                   none       none
Tray Factor                       1.000      3.889
Custom Blocks                        No         No
Block Edge Trans                  1.000      1.000
Height Point                 Isocenter  Isocenter
GCA (Internal)                    1.000      1.000
GCA (Transverse)                  1.000      1.000
Inverse Square                    1.008      1.008
Total Weight                     1250.0     1250.0
Weight / Rx                        50.0       50.0
Dose to Wt Pt / Rx                 90.0       90.0
Dose @ dmax / Rx                  133.9      103.9
Number of Fractions                  25         25
Rock Up Time (min)                 24.5       21.0
Machine Setting / Rx          103.1 MU   156.7 MU

Plan Checked by _____          Plan Approved by _____

        SSCI Development System - Prowess 1000 Vers 3.01 External
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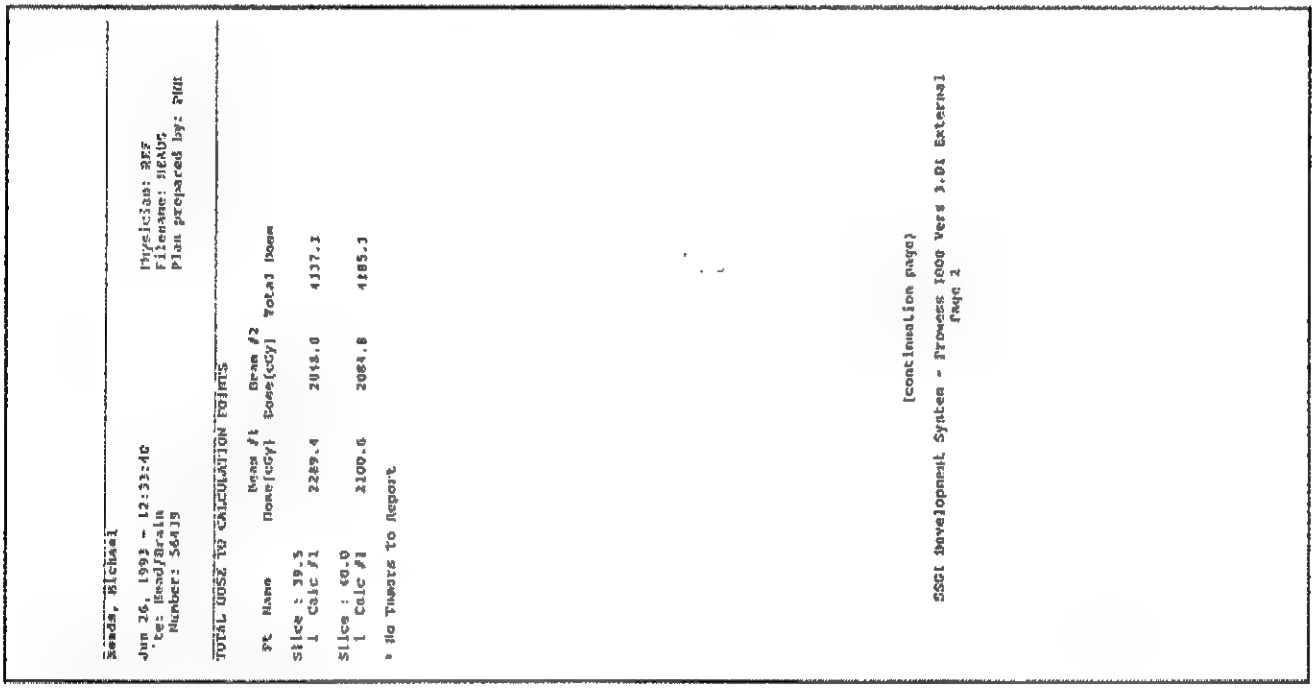
Figure 12.9 - Wedged Pair Calculation Results



```
Wedge, Michael

Jun 26, 1993 - 12:33:40                    Physician: REF
Site: Head/Brain                           Filename: WEDGE
Number: 56419                              Plan prepared by: PWM

TOTAL DOSE TO CALCULATION POINTS

                    Beam #1    Beam #2
Pt  Name          Dose(cGy)  Dose(cGy)  Total Dose

Slice : 39.5
  1  Calc #1         2289.4     2048.0      4337.3

Slice : 40.0
  1  Calc #1         2100.6     2084.8      4185.3

* No Tumors to Report

                    (continuation page)

        SSCI Development System - Prowess 1000 Vers 3.01 External
                                Page 2
```

Figure 12.10 - Wedged Pair Dose Summary

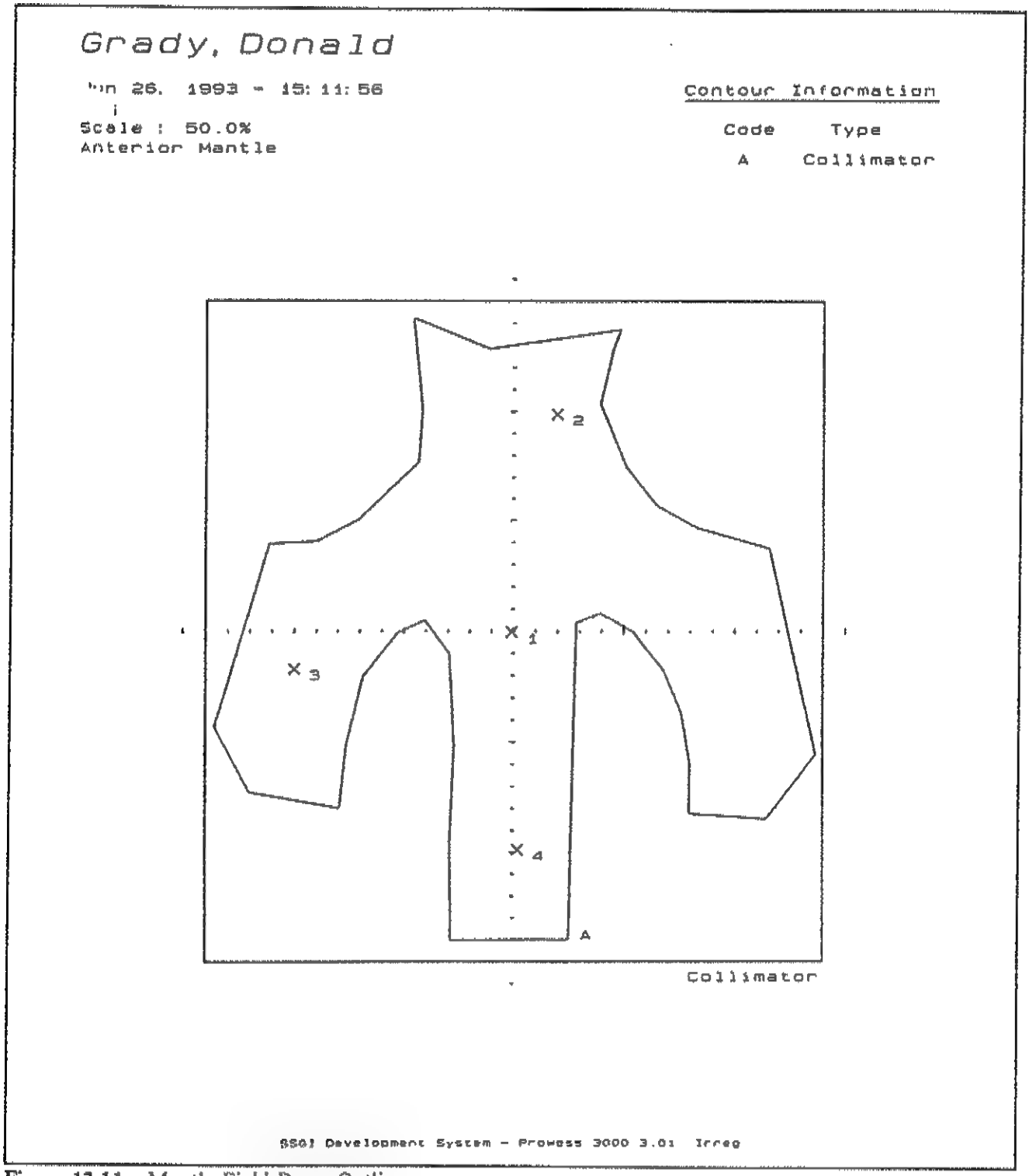


Figure 12.11 - Mantle Field Beam Outline

Grady,Donald

ɳ 26, 1993 - 15:11:56
..te: Anterior Mantle
ID Number: 12345
Plan prepared by: Your Name

Physician: CJ
Filename: grady
Primary Field

Calculation Results

Machine	LINAC-6X	Collimator Width (cm)	28.0
Prescribed Dose (cGy)	90.0	Collimator Length (cm)	30.0
Dose to Point Number	1	Tray Factor	0.970
Output Factor	1.077		
Machine Setting	131.9 Monitor Units		

Point Summary

Description	Point 1 CA	Point 2 Neck	Point 3 Axilla	Point 4 Lower
SSD (cm)	100.0	105.0	101.0	94.0
X position (cm)	-0.1	2.0	-10.0	0.2
Y position (cm)	-0.0	9.9	-1.7	-9.9
Depth (cm)	10.0	5.0	9.0	14.0
SMR	0.166	0.082	0.132	0.134
? zero	0.641	0.835	0.672	0.525
Edge Factor	0.939	0.938	0.939	0.939
Profile Factor	1.000	1.026	1.026	1.026
TMR	0.807	0.917	0.803	0.659
Equi. Sqr.(cm)	14.767	11.561	11.151	10.304
Dose (cGy)	90.0	103.7	91.2	77.7

Plan Approved by _____

SSGI Development System - Prowess 3000 Vers 3.01 Irreg

Figure 12.12 - Mantle Field Calculation Results and Dose Summary

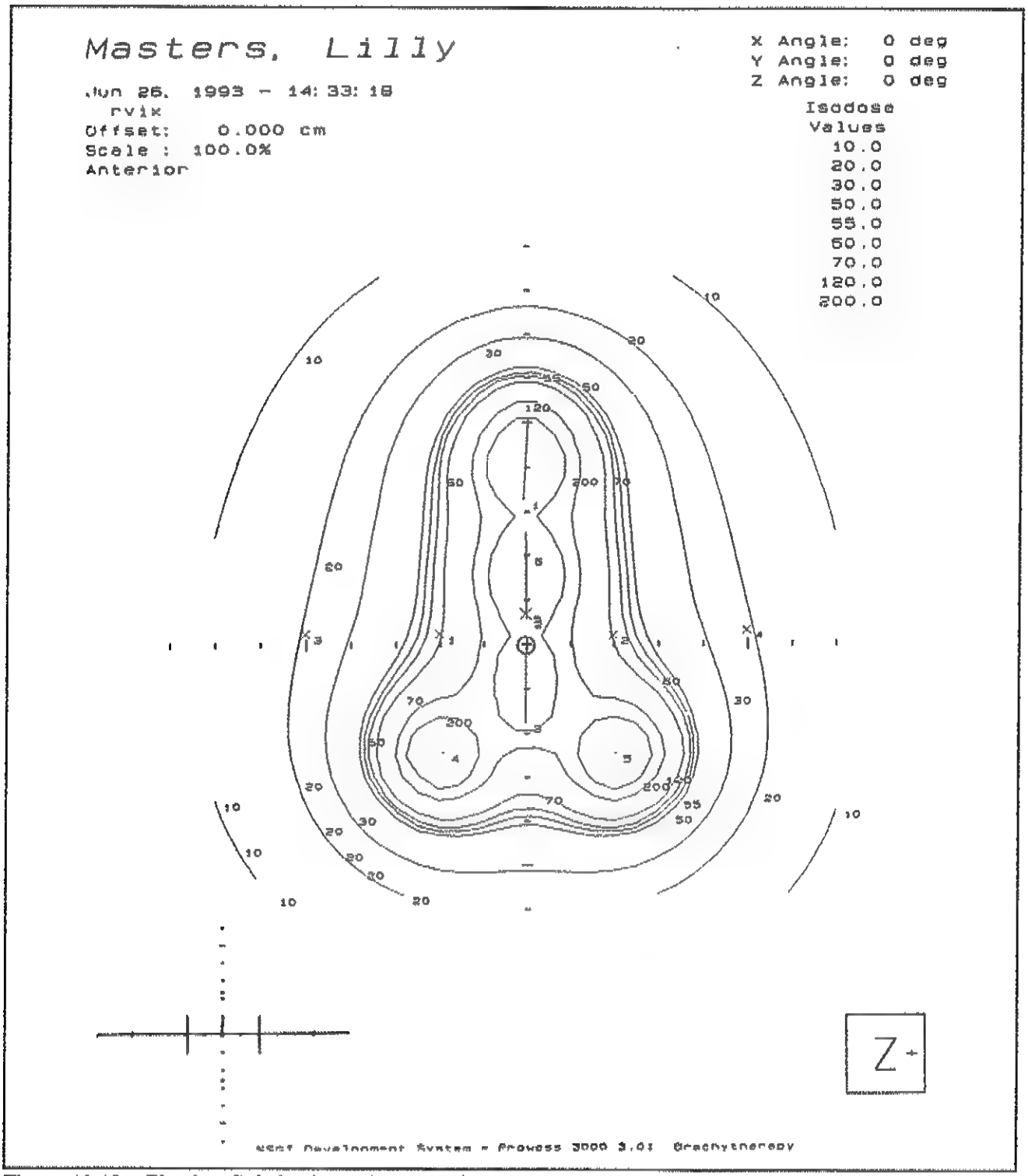


Figure 12.13 - Fletcher Suit Isodose Plot: AP View

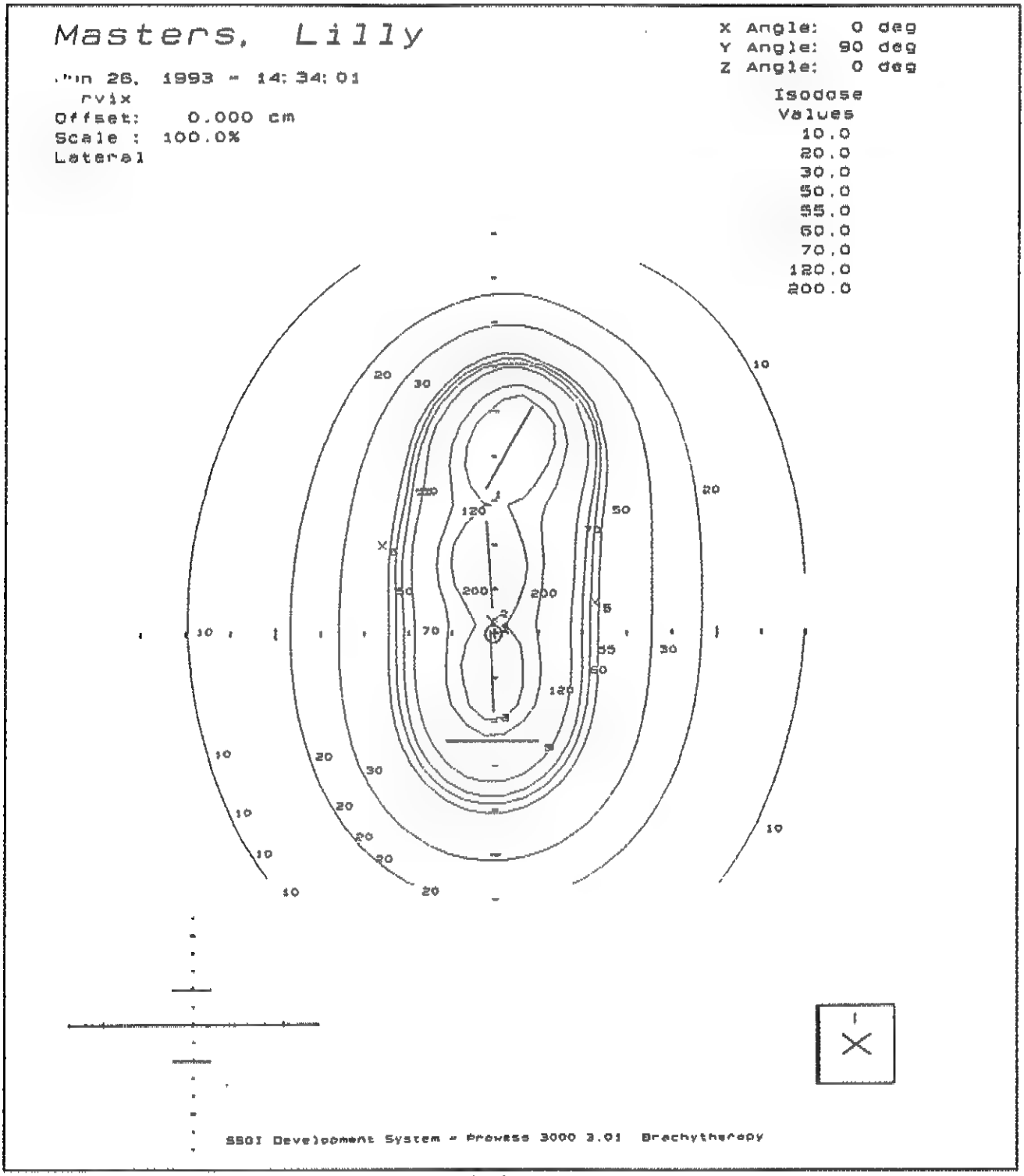
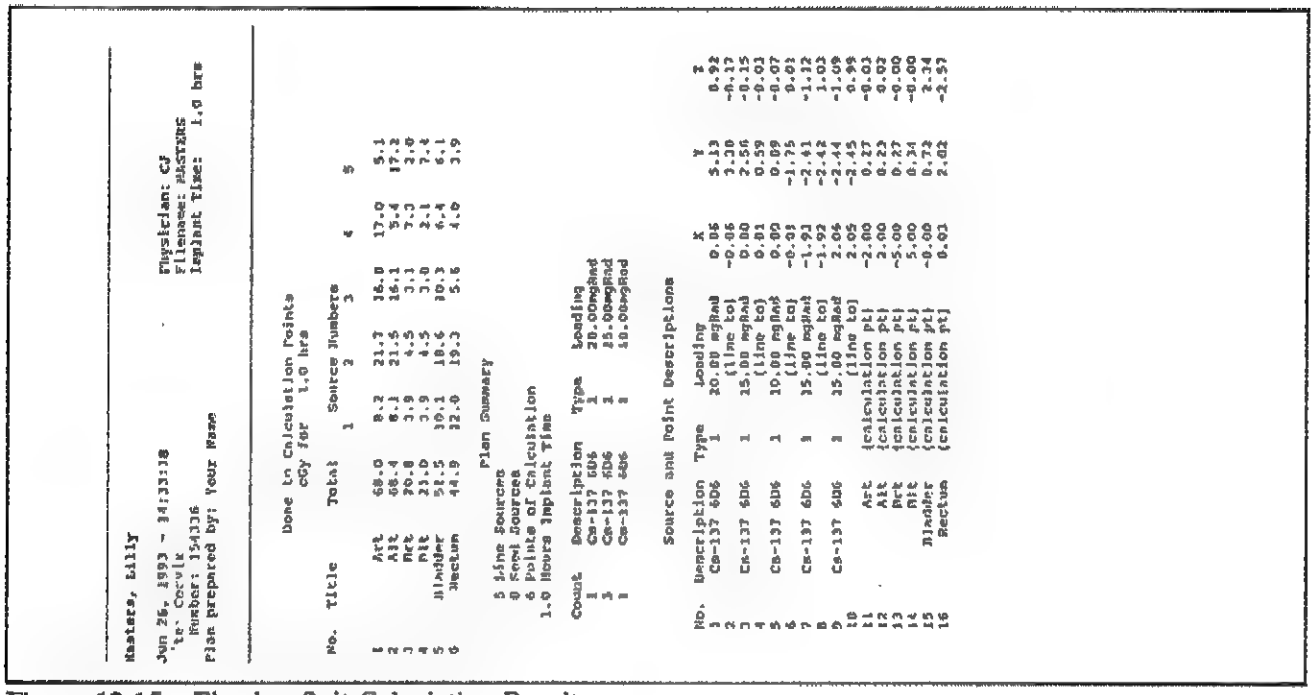


Figure 12.14 - Fletcher Suit Isodose Plot: Lateral View



Masters, Billy

Jun 26, 1993 - 14:33:18
Te: Corvik
Number: 154336
Plan prepared by: Your Name

Physician: CJ
Filename: MASTERS
Implant Time: 1.0 hrs

Dose to Calculation Points
cGy for 1.0 hrs

No.	Title	Total	Source Numbers 1	2	3	4	5
1	Art	68.0	8.2	21.7	16.0	17.0	5.1
2	Alt	68.4	8.1	21.5	16.1	5.4	17.2
3	Rct	20.8	3.9	4.5	3.1	7.3	2.0
4	Rlt	21.0	3.9	4.5	3.0	2.1	7.4
5	Bladder	52.5	10.1	18.6	20.3	6.4	6.1
6	Rectum	44.9	12.0	19.3	5.6	4.0	3.9

Plan Summary

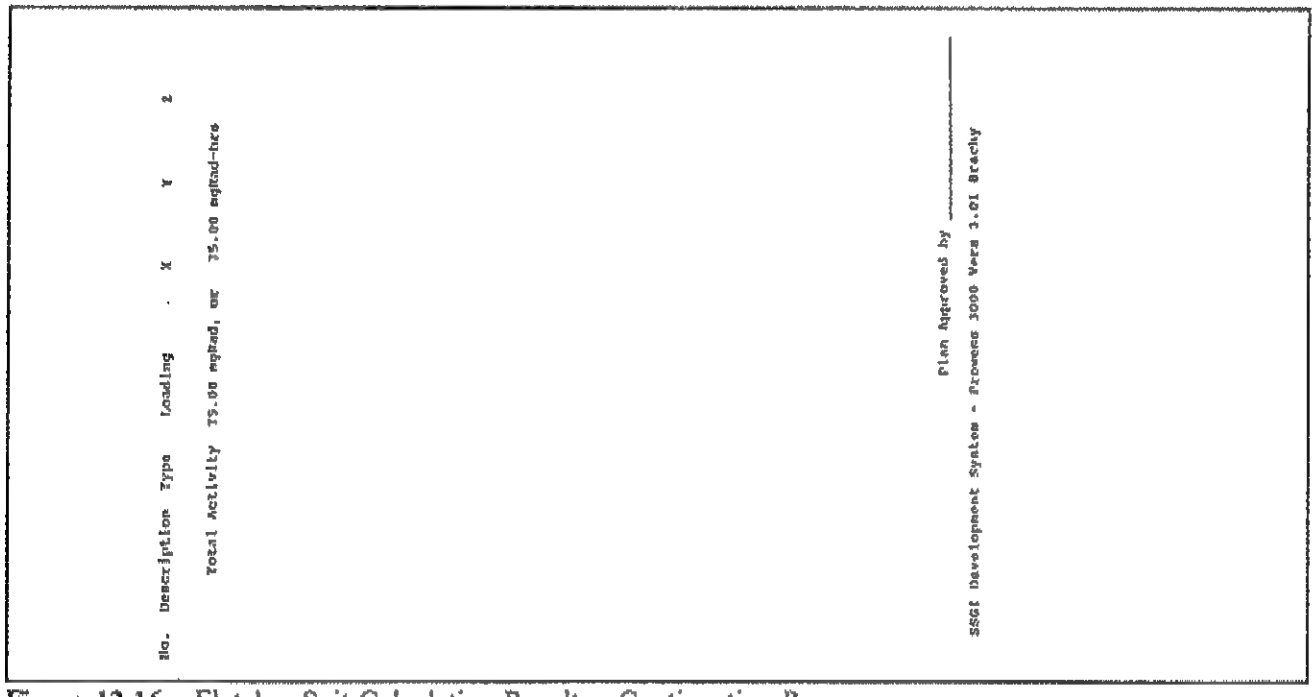
5 Line Sources
0 Seed Sources
6 Points of Calculation
1.0 Hours Implant Time

Count	Description	Type	Loading
1	Cs-137 606	1	20.00mgRad
5	Cs-137 606	1	15.00mgRad
1	Cs-137 606	1	10.00mgRad

Source and Point Descriptions

No.	Description	Type	Loading	X	Y	Z
1	Cs-137 606	1	20.00 mgRad	0.05	3.13	0.92
2			(line tot)	-0.05	1.30	-0.12
3	Cs-137 606	1	15.00 mgRad	0.00	2.56	-0.15
4			(line tot)	0.01	0.59	-0.01
5	Cs-137 606	1	10.00 mgRad	0.00	0.09	-0.07
6			(line tot)	-0.01	-1.75	0.01
7	Cs-137 606	1	35.00 mgRad	-1.91	-2.41	-1.12
8			(line tot)	-1.92	-2.42	1.03
9	Cs-137 606	1	35.00 mgRad	2.06	-2.44	-1.09
10			(line tot)	2.05	-2.45	0.95
11		Art	(calculation pt)	-2.00	0.27	-0.01
12		Alt	(calculation pt)	2.00	0.23	0.02
13		Rct	(calculation pt)	-5.00	0.27	-0.00
14		Rlt	(calculation pt)	5.00	0.34	-0.00
15		Bladder	(calculation pt)	-0.00	0.72	2.34
16		Rectum	(calculation pt)	0.03	2.02	-2.57

Figure 12.15 - Fletcher Suit Calculation Results



No.	Description	Type	Loading	X	Y	Z

Total Activity 75.00 mgRad, or 75.00 mgRad-hrs

Plan Approved by _____

SSGI Development System - Prowess 3000 Vers 3.01 Brachy

Figure 12.16 - Fletcher Suit Calculation Results: Continuation Page

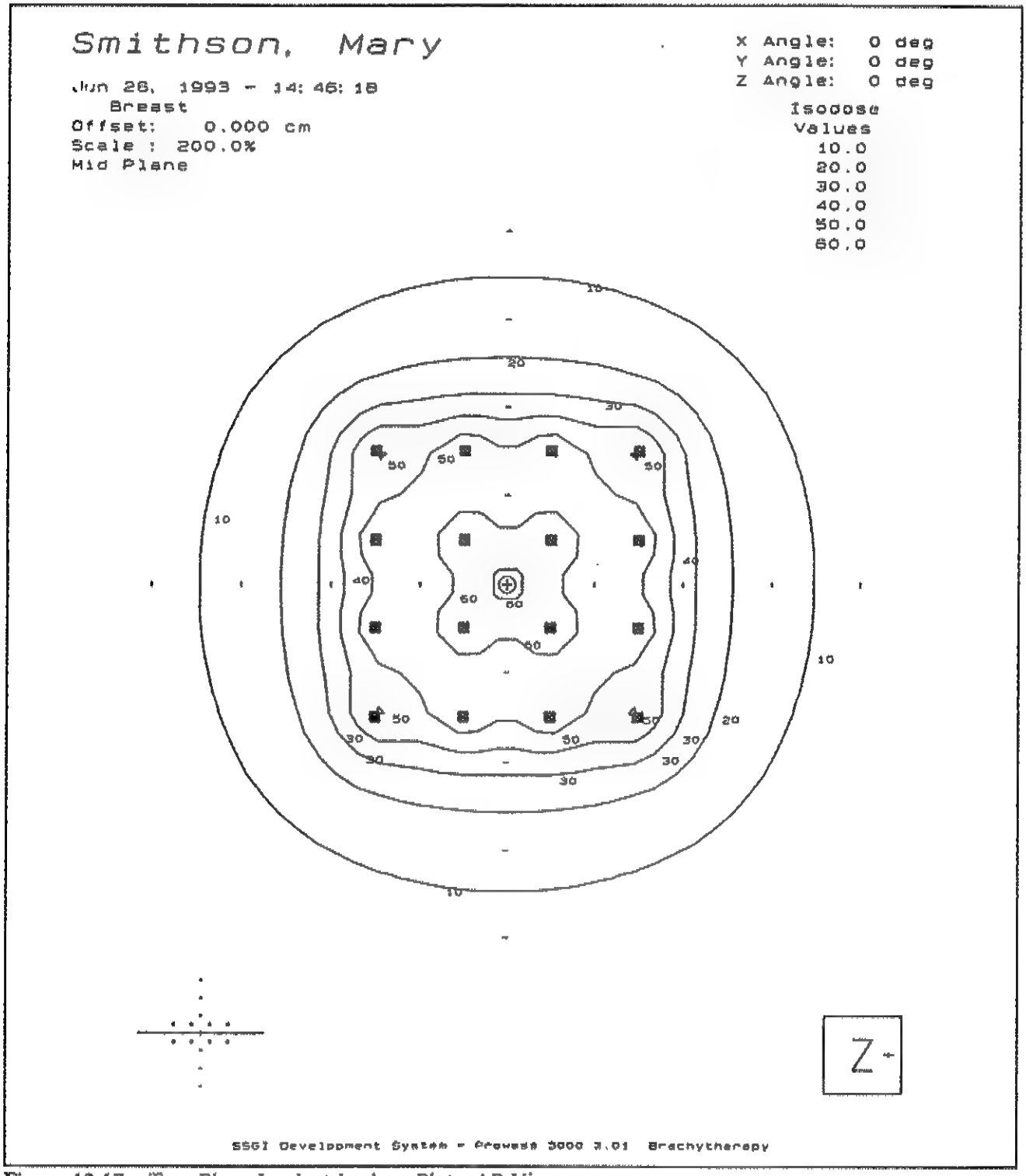


Figure 12.17 - Two Plane Implant Isodose Plot: AP View

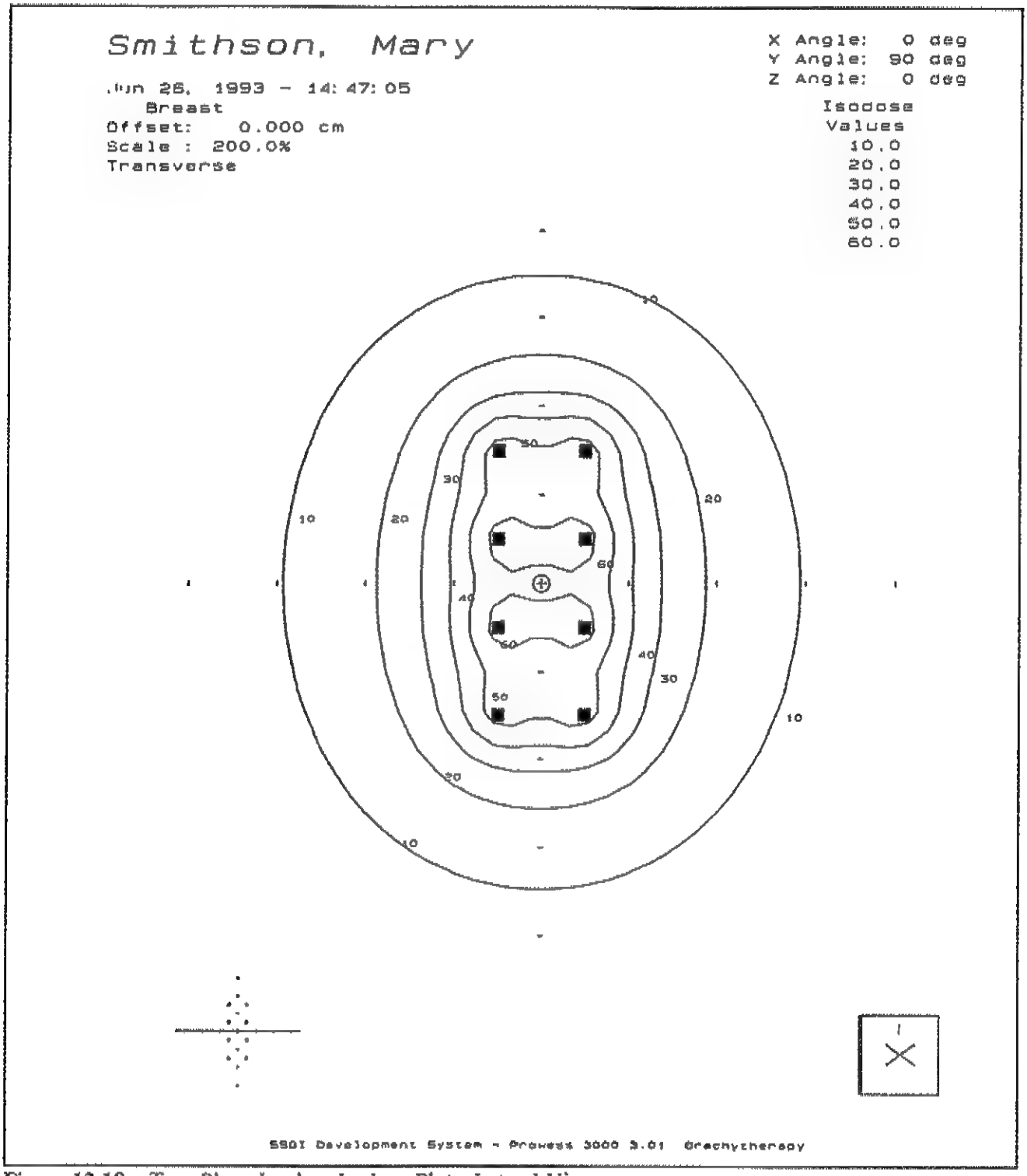
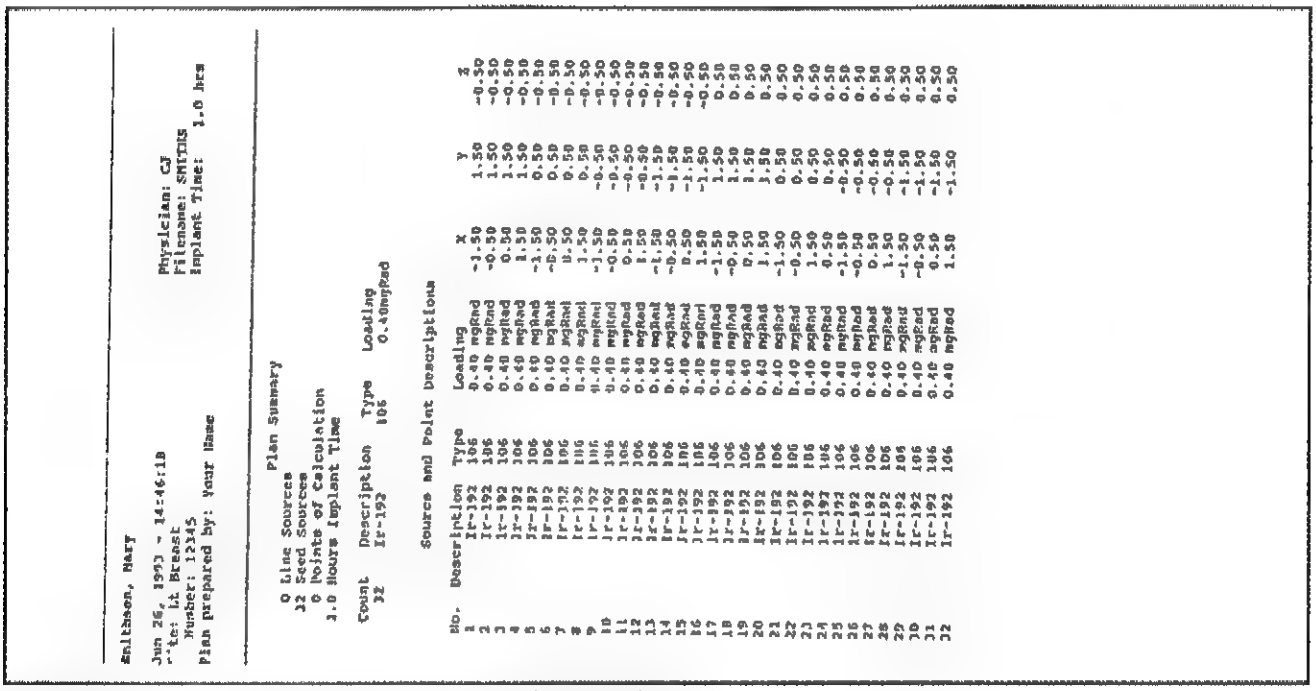


Figure 12.18 - Two Plane Implant Isodose Plot: Lateral View



Smithson, Mary

Jun 26, 1993 - 14:46:18
Site: Lt Breast
Number: 12345
Plan prepared by: Your Name

Physician: GJ
Filename: SMITHS
Implant Time: 1.0 hrs

Plan Summary

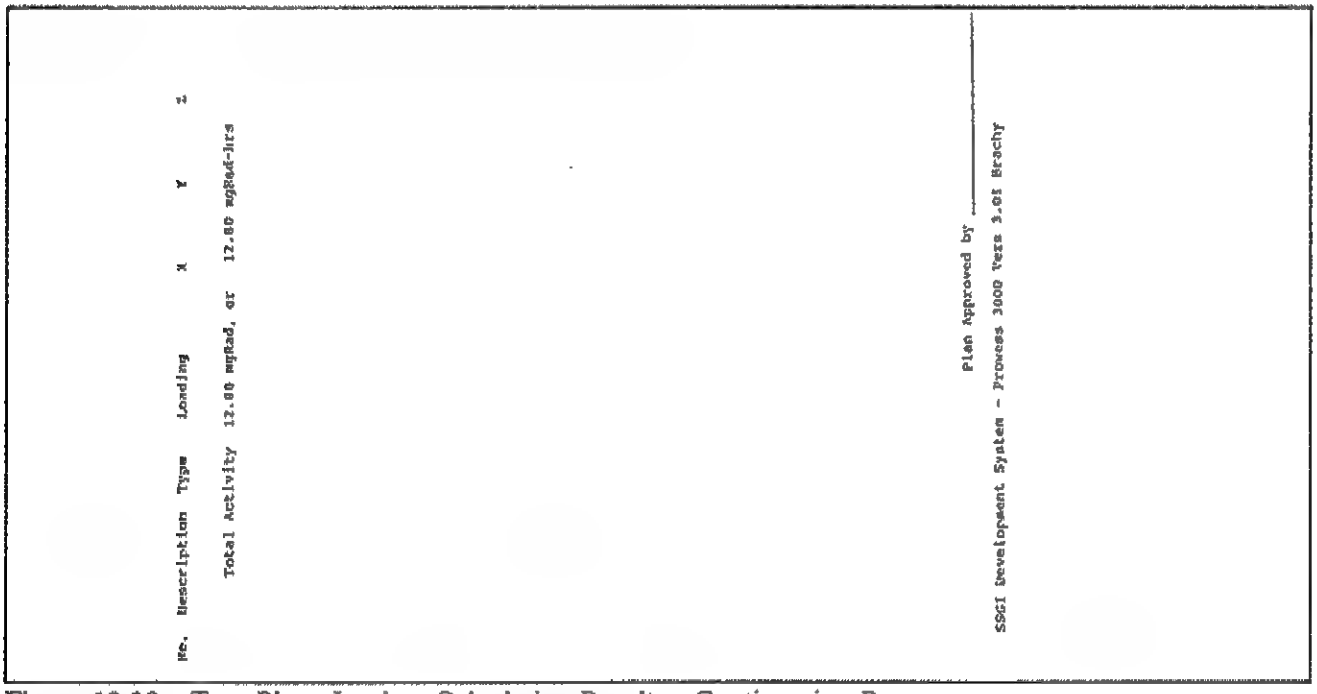
0 Line Sources
32 Seed Sources
0 Points of Calculation
1.0 Hours Implant Time

Count	Description	Type	Loading
32	Ir-192	106	0.40mgRad

Source and Point Descriptions

No.	Description	Type	Loading	X	Y	Z
1	Ir-192	106	0.40 mgRad	-1.50	1.50	-0.50
2	Ir-192	106	0.40 mgRad	-0.50	1.50	-0.50
3	Ir-192	106	0.40 mgRad	0.50	1.50	-0.50
4	Ir-192	106	0.40 mgRad	1.50	1.50	-0.50
5	Ir-192	106	0.40 mgRad	-1.50	0.50	-0.50
6	Ir-192	106	0.40 mgRad	-0.50	0.50	-0.50
7	Ir-192	106	0.40 mgRad	0.50	0.50	-0.50
8	Ir-192	106	0.40 mgRad	1.50	0.50	-0.50
9	Ir-192	106	0.40 mgRad	-1.50	-0.50	-0.50
10	Ir-192	106	0.40 mgRad	-0.50	-0.50	-0.50
11	Ir-192	106	0.40 mgRad	0.50	-0.50	-0.50
12	Ir-192	106	0.40 mgRad	1.50	-0.50	-0.50
13	Ir-192	106	0.40 mgRad	-1.50	-1.50	-0.50
14	Ir-192	106	0.40 mgRad	-0.50	-1.50	-0.50
15	Ir-192	106	0.40 mgRad	0.50	-1.50	-0.50
16	Ir-192	106	0.40 mgRad	1.50	-1.50	-0.50
17	Ir-192	106	0.40 mgRad	-1.50	1.50	0.50
18	Ir-192	106	0.40 mgRad	-0.50	1.50	0.50
19	Ir-192	106	0.40 mgRad	0.50	1.50	0.50
20	Ir-192	106	0.40 mgRad	1.50	1.50	0.50
21	Ir-192	106	0.40 mgRad	-1.50	0.50	0.50
22	Ir-192	106	0.40 mgRad	-0.50	0.50	0.50
23	Ir-192	106	0.40 mgRad	1.50	0.50	0.50
24	Ir-192	106	0.40 mgRad	0.50	0.50	0.50
25	Ir-192	106	0.40 mgRad	-1.50	-0.50	0.50
26	Ir-192	106	0.40 mgRad	-0.50	-0.50	0.50
27	Ir-192	106	0.40 mgRad	0.50	-0.50	0.50
28	Ir-192	106	0.40 mgRad	1.50	-0.50	0.50
29	Ir-192	106	0.40 mgRad	-1.50	-1.50	0.50
30	Ir-192	106	0.40 mgRad	-0.50	-1.50	0.50
31	Ir-192	106	0.40 mgRad	0.50	-1.50	0.50
32	Ir-192	106	0.40 mgRad	1.50	-1.50	0.50

Figure 12.19 - Two Plane Implant Calculation Results



No.	Description	Type	Loading	X	Y	Z

Total Activity 12.80 mgRad, or 12.80 mgRad-hrs

Plan Approved by _____

SSGI Development System - Prowess 3000 Vers 3.01 Brachy

Figure 12.20 - Two Plane Implant Calculation Results: Continuation Page

SSGI Machine Data Evaluation Report

File Name: _____ Energy: _____ Photon ____ Electron _____

Institution _____ Manufacturer: _____ Model _____

Evaluationed Done by: _____ Date: _____

Pass	Fail	Mode		Evaluation Parameters	Yes
Pass	Fail	General		Default Block Tray Factor	___
				Electron	___
				Photon	___
				Name satisfactory	___
				Dmax reasonable	___
				Comment: _____	
Pass	Fail	Depth Dose		Smooth	___
				Includes Zero Depth	___
				Comment: _____	
Pass	Fail	TMR		Extrapolates to 50+cm deep	___
				Extrapolates to 50-60 cm field size	___
				Extrapolates to zero field size	___
				Uniform TMR data	___
				Comment: _____	
Pass	Fail	SMR		Smooth	___
NA				Dmax all 1.00	___
				Enough Depths	___
				Comment: _____	
Pass	Fail	Output Factor		< = 25 Values	___
				Increasing field size	___
				Increasing order of magnitude with field size	___
				Normalize to 10 x 10	___
				Comment: _____	
Pass	Fail	Edge Factors		____ # Edge Types	___
				Increasing Distances	___
				.5 @ 0 cm	___
				Starts at Zero transmission	___
				Ends at 1.0 transmission	___
				Comment: _____	
Pass	Fail	Irreg Profiles		Increasing distances	___
NA				Smooth	___
				< = 25 Values	___
				Comment: _____	
Pass	Fail	Irreg HVL		Data valid	___
NA				Decreasing HVL with increasing distance	___
				< = 25 Values	___
				Comment: _____	

Pass	Fail	Mode		Evaluation Parameters	Yes
Pass	Fail		PSF	Data valid	___
NA				Increasing magnitude with increasing field size	___
				< = 25 Values	___
				Comment: _____	
Pass	Fail		Virtual SSD	Varies in uniform manner	___
NA				One value for each cone size	___
				Comment: _____	

OCR DATA	Open		Wedge # _____		Wedge # _____	
Orientation Correct (peak on RT)	Yes	No	Yes	No	Yes	No
Wedge factor for each field size	Yes	No	Yes	No	Yes	No
Wedge Type Correct	Yes	No	Yes	No	Yes	No
Wedge Name Present	Yes	No	Yes	No	Yes	No
Shape of Curve smooth and correct	Yes	No	Yes	No	Yes	No
Curve centered	Yes	No	Yes	No	Yes	No
Symmetric/Normalized Correctly	Yes	No	Yes	No	Yes	No
	Pass	Fail	Pass	Fail	Pass	Fail

	Wedge # _____		Wedge # _____		Wedge # _____	
Orientation Correct (peak on RT)	Yes	No	Yes	No	Yes	No
Wedge factor for each field size	Yes	No	Yes	No	Yes	No
Wedge Type Correct	Yes	No	Yes	No	Yes	No
Wedge Name Present	Yes	No	Yes	No	Yes	No
Shape of Curve smooth and correct	Yes	No	Yes	No	Yes	No
Curve centered	Yes	No	Yes	No	Yes	No
Symmetric/Normalized Correctly	Yes	No	Yes	No	Yes	No
	Pass	Fail	Pass	Fail	Pass	Fail

	Wedge # _____		Wedge # _____		Wedge # _____	
Orientation Correct (peak on RT)	Yes	No	Yes	No	Yes	No
Wedge factor for each field size	Yes	No	Yes	No	Yes	No
Wedge Type Correct	Yes	No	Yes	No	Yes	No
Wedge Name Present	Yes	No	Yes	No	Yes	No
Shape of Curve smooth and correct	Yes	No	Yes	No	Yes	No
Curve centered	Yes	No	Yes	No	Yes	No
Symmetric/Normalized Correctly	Yes	No	Yes	No	Yes	No
	Pass	Fail	Pass	Fail	Pass	Fail

Comments: _____

PROWESS *3000* HARDWARE SETUP CHECKLIST

(Check off boxes as you complete each item)

☐ Unbox all units:
- ☐ CPU
- ☐ Monitor
- ☐ Printer
- ☐ Digitizer
- ☐ Scanner
- ☐ Plotter

- Make sure *all* items are removed from boxes (especially HP printers and plotters).
  CHECK PACKING LIST
- Follow instructions with each unit for unpacking and assembly

☐ Remove cardboard 5¼" floppy drive protector from CPU.
☐ Lock scanner bulb in place above scanner surface.
☐ Unlock scanner carriage (**VERY IMPORTANT** - see manual)
☐ Plug in surge protector - *TURN IT OFF*
☐ Attach all power cords to units. Plug into surge protector.
☐ Attach cable from monitor to CPU.
☐ Plug mouse and keyboard into CPU ports.
☐ Attach scanner cable from scanner to interface port on CPU.
☐ Attach Prowess security block (about 2" x 2" x ½") on LPT1 of CPU.
☐ Attach printer cable from printer to CPU.
(LPT2 if you have a PaintJet plotter; LPT1 if using other plotter)
☐ Attach cable from Plotter to CPU.
(LPT1 if PaintJet; COM1 or 2 for other plotter)

DIGITIZER

☐ Assemble light stand according to enclosed diagram.
☐ Place digitizer on stand.
☐ Attach pen to electronics box and place pen on Velcro patch on digitizer tablet.
☐ If digitizer is Numonics Accugrid, place electronics box on legs of lightstand and attach cable from electronics box to tablet.
☐ Attach cable from digitizer to CPU port (COM1 or COM2).
☐ If using external modem, plug unit into surge protector, telephone line, and CPU (usually COM3).
☐ Turn surge protector on. All units should power on properly.

HARDWARE CONNECTIONS

The Prowess *3000* computer hardware is connected as shown in Figure B.1 and B.2

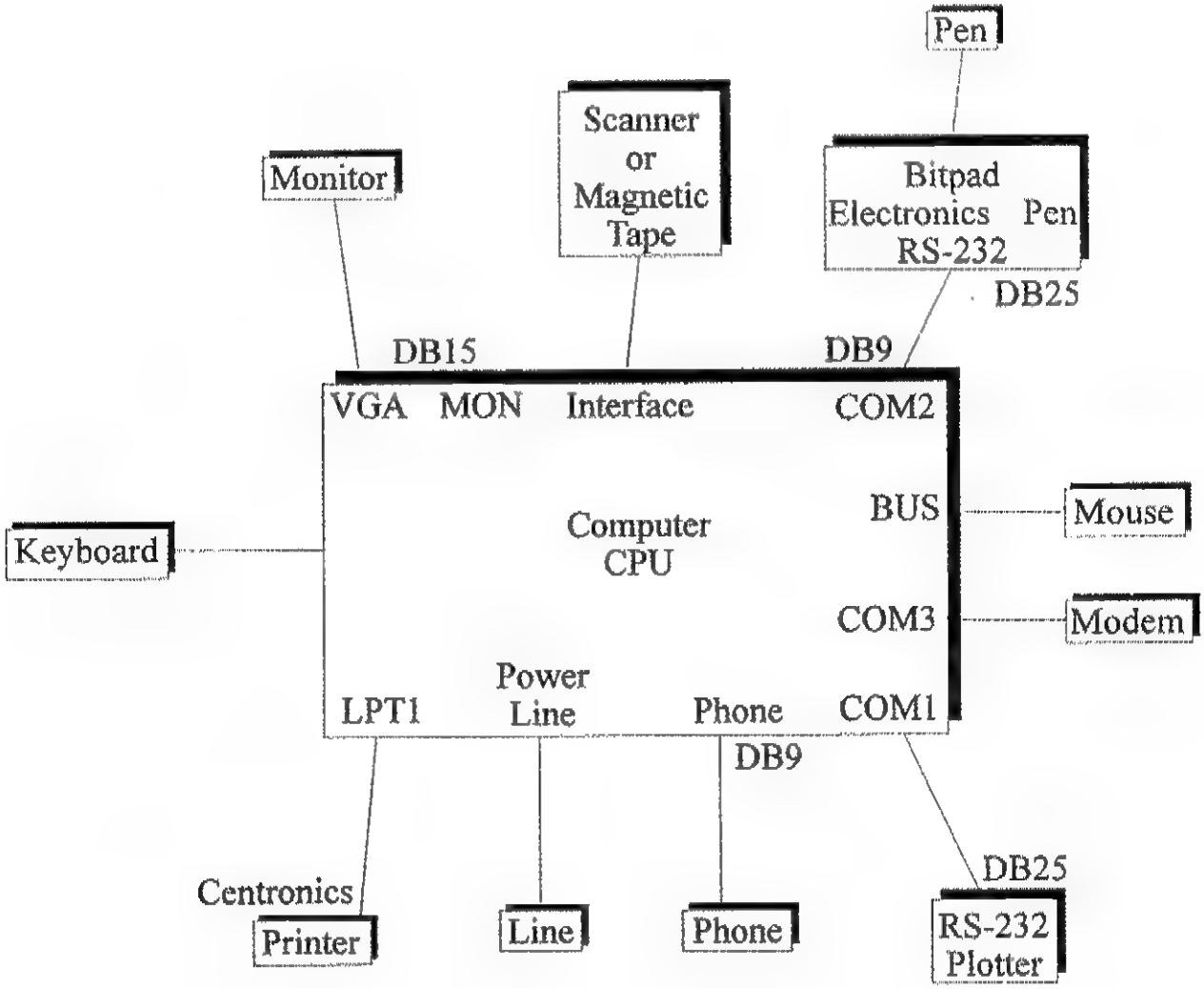


Figure B.1 - Signal Cable Interconnections

APPENDIX B
Hardware Connections

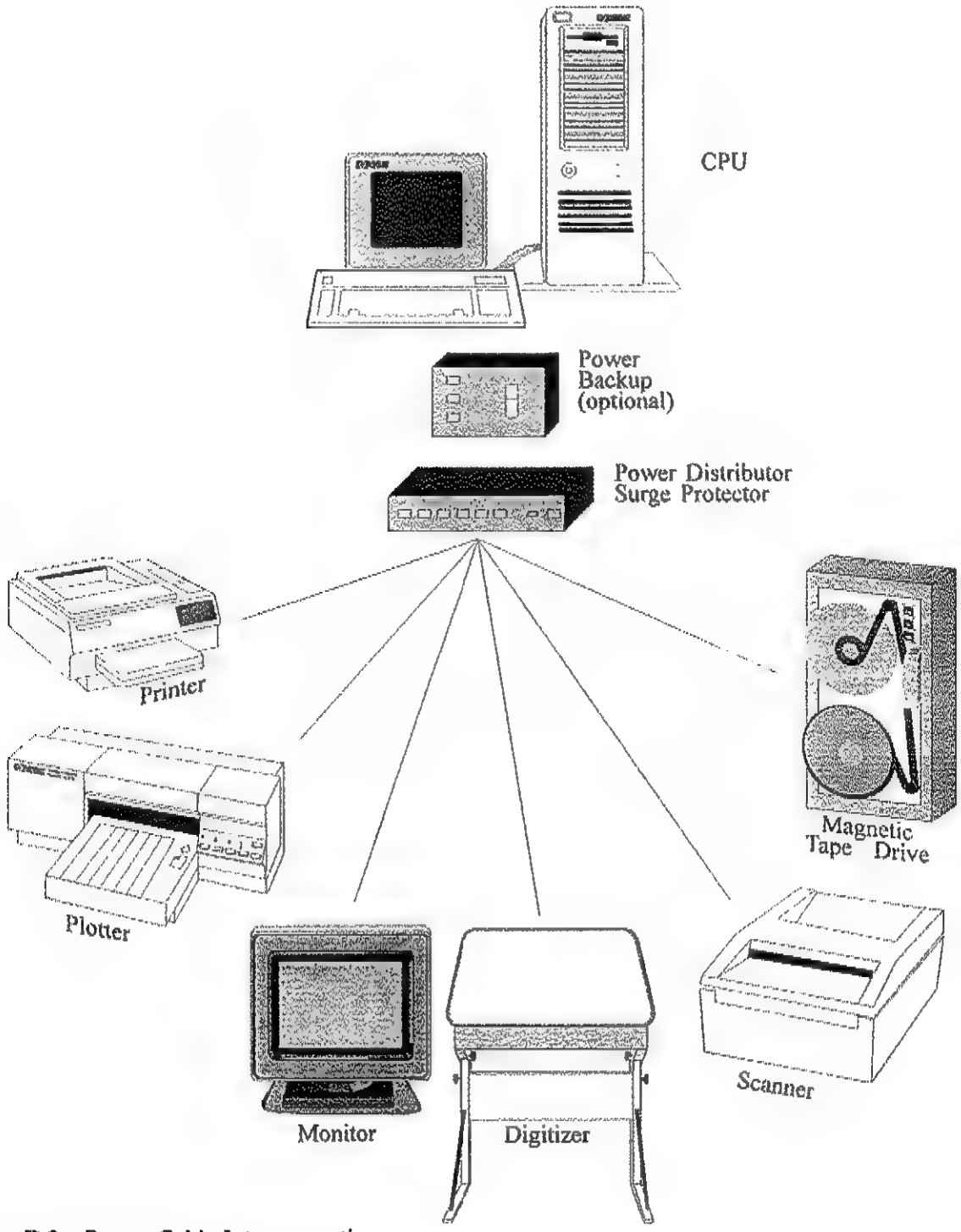


Figure B.2 - Power Cable Interconnections

Cable descriptions are as follows:

SCIENCE ACCESSORIES GRAF PEN OR NUMONICS TO DIGITIZER CPU

Graf Pen (DB25 Male)	CPU (DB9 Female)	CPU (DB25 Female)
2	3	2
3	2	3
7 ground	5	7
6&10 jumpered	4,6,7,8 jumpered	4,5,6,20 jumpered

HP PLOTTER TO CPU

7475A HP Plotter (DB25 Male)	CPU (DB9 Female)	CPU (DB25 Female)
2	2	3
3	3	2
5 & 6	4	20
7 ground	5	7
20	6&8	6&5

7550A HP Plotter (DB25 Female)	CPU (DB9 Female)	CPU (DB25 Female)
2	2	3
3	3	2
5 & 6	4	20
7 ground	5	7
20	6&8	6&5

PRINTER TO CPU (LPT1)

Printer	CPU
Standard Centronics Parallel Connector	Standard DB25 Male Connector

MONITOR TO CPU (VGA) Special 15 pin monitor cable to CPU

HARDWARE SETTINGS

SCIENCE ACCESSORIES GP7 MODEL II GRAFBAR

(2400 baud, 7 bit, even parity, 2 stop bits, menu off)
Must install pin 10 jumper
Use ROM with default start up of metric, menu off, extended range toward digitizer enabled

Switch Settings

1	Up	Stylus
2	Up	2400 Baud
3	Down	2400 Baud
4	Down	2400 Baud
5	Down	Parity even
6	Up	Parity yes
7	Up	Stylus

SCIENCE ACCESSORIES GP8 SONIC DIGITIZER

(2400 baud, 7 bit, odd parity, 2 stop bits, menu off)
Must install pin 10 jumper
Use ROM with default startup of metric

Switch Settings

1	Down (ON)	2400 Baud
2	Down	2400 Baud
3	Up (OFF)	2400 Baud
4	Up	Parity yes
5	Up	Odd parity
6	Up	Carriage return only
7	Up	Stylus
8	Up	Standard frame
9	Up	-----
10	Down	Menu Off

NUMONICS GRIDMASTER DIGITIZER

(2400 Baud, 8 bit, no parity, 1 stop bit, XON XOFF disables, Polled mode, 200 lpi (English, S-BPI ASCII)

Set up with set up program using menu. Press ASCII mode first and touch all other boxed. Exit with Save Configuration

APPENDIX C
Hardware Settings

NUMONICS MODEL 2200 20"X24" TRANSLUCENT TABLET

(2400 baud, 7 bit, no parity, 1 stop bit)

Baud rate (2400) mode switch ON, OFF, ON, OFF

Switch A(DS1)

1	Off	Point mode - enabled
2	On	Stream mode - disabled
3	On	Increment Stream Mode - disabled
4	On	Switch stream mode - disabled
5	On	Metric mode
6	On	Absolute mode - OFF
7	On	Standard ASCII mode
8	On	Polled mode - disabled

Switch B (DS2)

1	Off	Carriage return
2	On	No line feed
3	On	No parity
4	On	-----
5	On	1 stop bit
6	On	Audible - disabled
7	On	XON/XOFF - disabled
8	On	Self diagnostic - disabled

NUMONICS ACCUGRID 20"X24" TRANSLUCENT DIGITZER

(2400 baud, 8 bit, no parity, 1 stop bit)

Set up with menu:
Numonics ASCII
Point Mode
40 lines/mm resolution
CR, LF, Sep, Flag Options
Beep enabled
Save as Application 1

HEWLETT PACKARD 7475A PLOTTER

(9600 baud, 8 bit, no parity, 1 stop bit) Baud B1-0, B2-1, B3-0, B4-1, Size A3-1, Met US-1, Y-0, Parity S1-0, S2-0.

Pens:

1 - Black (.7 mm)
2 - Red (.3 mm)
3 - Green (.3 mm)
4 - Orange (.3 mm)
5 - Blue (.3 mm)
6 - Purple (.3 mm)

HEWLETT PACKARD 7550A PLOTTER SETUP

Serial 9600, 8 bit, no parity, 1 stop bit, hardware handshake HP-IB-Standard, bypass off, mode direct, remote, stand alone, half duplex, monitor mode off.

Pens:

1 - Black (.7 mm)
2 - Red (.3 mm)
3 - Green (.3 mm)
4 - Orange (.3 mm)
5 - Blue (.3 mm)
6 - Brown (.3 mm)
7 - Purple (.3 mm)
8 - Yellow (.3 mm)

LEXMARK IBM PS 4079 PRINTER

Main Menu:

Parallel only. Print quality - draft. Screening - enhanced. Color balance - plain or coded paper (indicate which). Emulation mode - Automatic. Start page - off. Auto scaling - off. Auto eject - on. Paper size - A (letter). Copies - 1. Load method - 1.

PS Menu:

Start page - off. Wait timeout - 300 seconds. Job timeout - disabled.

Plotter GL Menu:

Autoscaling - off. Timeout - 1 minute. Autoeject - off. Pen - 1-8. Width - 0.3 mm.

Pen	1	color	=	black
Pen	2	color	=	red
Pen	3	color	=	green
Pen	4	color	=	yellow
Pen	5	color	=	blue
Pen	6	color	=	red - violet
Pen	7	color	=	aqua
Pen	8	color	=	orange

Interface Menu:

Parallel Prot. - fastbytes. Honor Init - off.

HEWLETT PACKARD PAINTJET XL WITH HPGL CARTRIDGE

Parallel only, serial is too slow. Switch settings (BAUD0-0, BAUD1-0, PAR0-0, PAR1-0, XON/XOFF-0, MET-1, ROM8-0).

APPENDIX C
Hardware Settings

HEWLETT PACKARD PAINTJET XL300 WITH POSTSCRIPT

Parallel only. RS422-1, Baud0-0, Baud 1-0, Xon-Xoff-0, PCL5-0, PCL5-0, Roman8-0, 10 cpi-0, English-0.

HEWLETT PACKARD DESKJET 1200 C/PS

Parallel only. Switch settings

language	down	PCL5
language	down	PCL5
context	down	
centrone	down	
Roman 8	down	
12 cpi	down	
Letter/A4	down	
----	down	

HEWLETT PACKARD LASERJET SERIES III PRINTERS SETUP

Set default font to **PC-8** of 10 cpi (Internal 32)
Page Protection to LTR

HEWLETT PACKARD LASERJET SERIES 4 PRINTERS

Set default font to PC-8 of 10 cpi, page protection to LTR

XRS 3CX OR 6CX OMNIMEDIA COLOR FILM SCANNER

Interface card switch settings: 1 & 5 down, all the rest are up. (Address is 220.) Be sure that the system driver **MSCAN.SYS** is installed in the **CONFIG.SYS** file.

COMPUTER COMPONENTS

SERIAL COM PORT ADDRESSES

COM	Address	Interrupt Level
COM 3	3E8	IRQ 2 (Vector Address 34)
Bus Mouse		IRQ 5
COM 2		IRQ 3
COM 1		IRQ 4

EVEREX MAGIC I/O SERIAL BOARD MODEL 170B

COM 3

SW1

1	Off
2	Off
3	On
4	Off

LPT Jumper Off

Interrupt 2 Jumpers

o o o o o o
o o o o o o
o o o o o o
↓ ↓ ↓ ↓ ↓ ↓
Serchint Lptsel

CONTROL FILE EDITING

There is a master control file that reconfigures the entire Prowess *3000* system. It is a text file which can be changed. However, care must be taken before making any changes as it can have significant effects on the operation of the program.

The name of the control file is **TPS.CTL** and is located in the root (C:\) directory of your hard disk drive. Each time this file is updated, the treatment planning programs recompile the file into a usable format. Be sure the security plug is in place before changing the control file.

If the security plug is not present, "Demo Version" will appear in the upper left corner and many functions will not work. If the control file is compiled without the security plug in, all input/output functions will be disabled until the program is recompiled with the plug in place.

To edit the control file, choose the **Configuration** option from the main Prowess *3000* menu. Then choose **Edit Configuration** from this second menu. The system uses PC-Lite, a shareware word processor or the DOS editor to edit this file. The control file will appear as a text file. Use the arrow keys and page up and down to move through the file. The insert, backspace, and delete keys work as expected. To end the session, **F1 (help)** then **F2 or Alt-E Alt-Q (Quit)**. This action automatically saves the file. The next time you run Prowess *3000*, the control file will be compiled for use with the treatment planning programs.

The control file is a text file written in pseudo-English terms. An active line or command starts with a ">" symbol in column one followed by a command. The command is usually one or more words in all capital letters. For example:

>USER AUTHORIZATION NAME IS 'Demonstration Site'
means that the facility name printed at the bottom of the hardcopy is entitled "Demonstration Site."

All other lines are treated as comments and should start with a blank space or a semicolon (;).

The file has been organized by category The general categories include:
- Display adapters' parameters
- Name, authorization code, and version number
- File location paths
- Display colors
- Menu and submenu items
- Peripheral Device list, location, and settings
- Serial port parameters
- CT data format
- Bitpad calibration data
- Plotter settings and paper size
- Default program settings such as isodose curves

The exact format of each command line is important. Before changing any line, be sure you understand its format and usage. Should you have any questions concerning this file, please call Technical Support at SSGI (916) 898-0660 between the hours of 8:30 a.m. and 5:00 p.m. Pacific Time.

SYSTEM FILE MANAGEMENT

Invoking Pop-Up DOS

1. Select "Patient File Management" from the Prowess *3000* Configuration Menu.
2. Select "File Management" from the Prowess *3000* Main Menu.
3. Pop-Up DOS can be started from the C:\> prompt by typing "POPDOS".

Traversing Directories

DOS has a tree-like directory structure. To "go into" a directory simply select the directory name (i.e. [TPS]) with the mouse or cursor keys and strike <Enter> key

To go up one level to a parent directory select the [..] directory

Patient File Management

Prowess *3000* patient files are in two places:

1. \TPS\PATIENT
   Digitized contours for external beam, irregular field data, and brachytherapy source locations are all stored in this directory.
2. \TPS\CATIMAGE
   Scanned and tape images are stored in this directory.

Modifying File Display

The way files are displayed can be changed. Select Options/Directory Display to sort files by date, filename, or type of file (file extension).

Selecting Files

Files can be selected with the mouse or the keyboard. Tapping the space bar will highlight the file name. Clicking on the file under the mouse will also highlight the file.

Once a file or group of files are selected, they can be copied, deleted, or removed. Choose File to perform the desired function to these files.

Warning: Be sure the files are copied to the backup media before deleting them.

Formatting a Floppy Disk

Insert floppy diskette into the drive. Select Disk/Format from Pop-Up DOS menu. A screen will come up asking for volume name (usually leave blank), diskette format (either 1.2 Mbytes 5.25" or 1.44 Mbytes 3.5"), and diskette drive (A: or B:). Pick the correct sizes and select OK.

Copying Files

Once files are selected, they can be copied to another directory or a floppy disk. Select File/Copy If copying to a floppy drive, type **A:** or **B:**. If copying to another directory, type the path of the directory (i.e., C:\TPS\OLDPAT\).

Deleting Files

Selected files can be deleted by choosing File/Delete (Note: Delete *must* be selected wtih the mouse. Pop-Up DOS does not allow the keyboard command to work).

Checking Hard Disk

Pop-Up DOS has the facility of checking the hard disk for lost clusters or chains. Select Disk/Check Disk to activate.

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